Implementing home-based exercise programs for community-dwelling older adults in New South Wales, Australia

Amanda Michelle Macaulay

BSc (Human Movement Science and Nutrition), Master of Public Health,

MSc (Nutrition and Dietetics)

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Supervisor's statement

As the primary supervisor of Amanda Macaulay's doctoral work, I certify that I consider her thesis "Implementing home-based exercise programs for community-dwelling older adults in New South Wales, Australia"
to be suitable for examination.

Professor Anne Tiedemann
Institute for Musculoskeletal Health
Sydney School of Public Health
Faculty of Medicine and Health
The University of Sydney, Australia

14 December 2025

Candidate's statement

This thesis is submitted to The University of Sydney in fulfilment of the requirement for the Degree of Doctor of Philosophy.

I, Amanda Macaulay (Bates), certify that the intellectual content of this thesis is the product of my own work, and that all assistance received in preparing this thesis and all sources have been acknowledged. This thesis does not contain material which has been submitted in part or in full for any other degree at this or any other institution.

I, Amanda Macaulay (Bates), understand that if I am awarded a higher degree for my thesis entitled "Implementing home-based exercise programs for community-dwelling older adults in New South Wales, Australia" being lodged herewith for examination, the thesis will be lodged in the University Library and will be available immediately for use. I agree that the University Librarian (or in the case of a department, the Head of Department) may supply a photocopy or microform of the thesis to an individual for research or study or to a library.

Amanda Macaulay (Bates)

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17 December 2025

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Publications and presentations

Parts of the work presented in this thesis have been published or are under review in peer-reviewed journals or presented in the following forms:

Publications

Bates A, Furber S, Tiedemann A, Ginn K, van den Dolder P, Howard K, Bauman A, Chittenden C, Franco L, Kershaw M, Sherrington C (2018) Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at Home randomised, controlled trial. *Journal of Physiotherapy* 64: 121. https://doi.org/10.1016/j.jphys.2017.10.001

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Presentations (presenter in bold)

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Attribution statement regarding the use of Artificial Intelligence

During my candidature, Artificial Intelligence (AI) tools have become increasingly available and have expanded their use for learning and research.

In the preparation of this thesis, some AI (Chat GPT and Copilot) was used for conducting literature searches for specific articles and troubleshooting formatting challenges. All AI generated suggestions were critically reviewed and the original sources verified to ensure academic integrity. The use of AI aided my learning and facilitated the resolution of formatting challenges.

I, Amanda Macaulay, confirm that any AI use adhered to the University of Sydney guidelines for use of generative AI in learning and assessment Research - Generative-AI: guidelines for researchers and I take full responsibility for the submitted thesis.
All research and intellectual content remain entirely my own work unless otherwise cited.

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Amanda Macaulay (Bates), 17 December 2025

Preface

The work presented in this thesis is organised into seven chapters, written so that each chapter can be read independently. The University of Sydney allows published papers that arose from the candidature to be included in the thesis.

Chapter One is an introduction to the thesis and provides background information for the following chapters. It also highlights the importance of physical activity for healthy ageing and how home-based exercise programs can assist older adults meet the recommendations for physical activity.

Chapter Two is a literature review of home-based exercise programs for older adults. It overviews the evidence about the features and efficacy of home-based exercise in relation to preventing falls in older adults and people with COPD and improving shoulder function in community-dwelling older adults.

Chapter Three is the study protocol for the BEST (Balance Exercise Strength Training) at Home randomised controlled trial 'Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people'. This manuscript is presented as published as a trial protocol in the *Journal of Physiotherapy*.

Chapter Four is a randomised controlled trial evaluating the impact of a home-based exercise program for preventing falls in older people. This manuscript is presented as published in *BMC Geriatrics*.

Chapter Five is the report of the upper limb component of the randomised controlled trial evaluating the impact of a home-based upper limb exercise program for improving upper limb function among community-dwelling people aged 65+ years. This manuscript is currently under review and is presented in the format required by *PLOS One*.

Chapter Six is a pre and post study evaluating the acceptability, feasibility and effect of a home-based exercise program to prevent falls in people with COPD accessing virtual care. This manuscript is presented as published in the in the format required by the *International Journal of Chronic Obstructive Pulmonary Disease.*

Finally, **Chapter Seven** is an overview of the body of work and discusses the findings, implications for future practice and research in relation to home-based exercise programs for older adults.

Each chapter contains its own reference list. Ethical approval was gained from the University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee for studies presented in Chapters Three, Four, Five and Six prior to commencement of recruitment. All participants gave written informed consent before data collection began.

Abstract

The broad aim of this thesis was to investigate new ways to implement home-based exercise programs for community-dwelling older adults aged 65 years and over. Research methods included a large, pragmatic randomised controlled trial of 617 participants and a feasibility study delivered in the Illawarra and Shoalhaven areas in New South Wales (NSW), Australia.

As the global population ages, the prevention of falls and improving physical function in older adults becomes increasingly important. Falls, the most common cause of injury in older adults, results in injury, reduced quality of life and cost to the health system. Upper limb dysfunction, including shoulder pain and stiffness, is a major health issue for community-dwelling older adults. Shoulder pain is the third most common musculoskeletal disorder in adults, after back and neck pain. The prevalence of shoulder pain increases with age. Reduced shoulder range of motion has been identified to be associated with poor lower limb function and mobility in older adults, suggesting that mobility limitations in older adults can be related to both upper limb and lower limb dysfunction.

Falls, upper limb dysfunction and COPD were selected as focal issues because they represent interconnected and increasingly prevalent contributors to functional decline in older adults. While falls are well established as a leading cause of injury, emerging evidence highlights how upper limb problems, particularly shoulder pain and restricted mobility, can further compromise independence and daily activities. Reduced shoulder range of motion is also associated with poorer lower limb performance, indicating that impairments across the upper and lower limbs often coexist and amplify mobility limitations. In addition, older adults with

COPD commonly experience reduced muscle strength, poorer balance and limited exercise capacity, placing them at substantially higher risk of falls. Together, these conditions reflect overlapping pathways to disability, making them important targets for scalable home-based exercise interventions.

It has been well established that exercise, particularly balance and functional exercises, can reduce falls and injuries from falls. However, uptake and participation in balance and strength exercise at the level recommended to prevent falls is low. Home-based exercise programs have been shown to reduce falls in older people; however, most have been delivered via individual home visits and are resource intensive. Home-based exercise programs are preferred by some older people due to greater convenience, accessibility and lower cost.

This thesis addressed gaps in knowledge by investigating the efficacy of home-based exercise programs for older adults to prevent falls and reduce shoulder dysfunction. A review of the literature is presented in Chapter Two, which investigated the features and effectiveness of home-based exercise programs in preventing falls and improving upper limb function in community-dwelling older adults. While the review found a moderate amount of evidence for home-based exercise programs to prevent falls in older adults, the evidence was much more limited in relation to home-based exercise programs to prevent falls in older adults with COPD. Studies reported a positive impact on falls, physical function, balance and strength, however the reporting of falls as a primary outcome was limited in the studies focused on older adults with COPD. The evidence was extremely limited in relation to the use of home-based exercise programs in the prevention of upper limb dysfunction in older adults. The review concluded that more research was needed to determine the effectiveness of a scalable

model of delivering home-based exercise programs for the prevention of falls and shoulder dysfunction in older adults.

The study protocol for a randomised controlled trial is presented in Chapter 3. Objectives, methods and procedures are outlined for the prospectively registered pragmatic randomised controlled trial testing two home-based exercise interventions, one for the lower limb and one for the upper limb. The Template for Intervention Description and Replication (TIDieR) checklist is included for transparency and reproducibility. The population was community-dwelling adults aged 65 years and over, residing in the Illawarra and Shoalhaven areas in NSW, Australia. Participants were recruited using a variety of methods, including paid advertisements in local newspapers, media releases, radio interviews, distribution of flyers and other printed material promoting the study and presentations to community groups. Participants were randomly allocated to one of two home-based exercise programs, a lower limb program designed to improve balance and strength in the lower limb or an upper limb exercise program designed to improve upper limb strength and mobility. The intervention included three group-based exercise instruction sessions and participants were instructed to perform the exercises at home three times per week for a 12-month period. Participants were provided with all equipment required to complete the exercises at home. The primary outcome for the lower limb exercise program was the rate of falls over a 12-month period, as self-reported by participants with monthly calendars. The primary outcome for the upper limb exercise program was upper limb dysfunction as measured by the Disabilities of the Arm Shoulder and Hand (DASH) questionnaire at 12 months.

The results of the lower component of the trial (n = 617) are presented in Chapter 4. The trial found no difference in the primary outcome between the rate of falls in the intervention group compared to the control group (IRR 0.91, 95% CI 0.64 to 1.29, $p = 0.604$, $n = 579$). A significant improvement in the intervention group compared with the control group was found for fear of falling (measured by the short Falls Efficacy Scale-International) at 3, 6 and 12 months (mean difference (MD) = 0.50, 95% CI 0.2 to 0.8, $p = 0.004$; MD = 0.39, 95% CI 0.001 to 0.8, $p = 0.049$; MD = 0.46, 95% CI 0.006 to 0.9, $p = 0.047$), and gait speed (measured by the 4 m walk) at 3 months MD = 0.09 s, 95% CI 0.003 to 0.19, $p = 0.043$). Participants reported completing the exercises less than twice per week, with an average of 94 sessions (SD 63, range 0–287) over the 12-month intervention period. The program was well received by participants with most participants ($n = 184/228$, 81%) intending to continue the exercises and 218 out of 234 (93%) recommending the program to others aged 65 years and over. It was concluded that a more deconditioned or frail population was likely needed to benefit most from this style of intervention and additional strategies to enhance adherence were recommended.

The results of the upper limb component of the trial (n = 617) are presented in Chapter 5. The trial found no clinically important or statistically significant between-group difference in upper limb function (measured by the DASH) at 12 months (MD = 0.99, 95% CI -0.82 to 2.79, p=0.283, n=462). There were no significant between-group differences in shoulder range of motion, most measures of strength, physical activity (device-measured and self-report), quality of life and upper limb function at three and six months. Participants in the upper limb group reported performing the exercises twice per week, averaging 104 exercise sessions (SD 69, median 117, range 0-371) over the 12-month intervention period. The findings highlighted the need for further research to determine whether this type of

home-based exercise program benefits all older adults or is more useful for those with existing upper limb dysfunction. It was recommended that future work should explore combining upper and lower limb exercises to create a more comprehensive home program that supports strength and functional independence in adults aged 65 and over, especially for those unable to access group-based exercise programs. Given the high rates of shoulder dysfunction in older age and its emerging link to mobility limitations, additional research is also needed to identify optimal exercise protocols for preventing shoulder dysfunction in healthy older adults.

Chapter Six presents the results of a pilot trial of a six-month home-based balance and strength exercise program with virtual care support in patients with a diagnosis of COPD. People with COPD are a group that are at a higher risk of falls due to poorer balance, reduced muscle strength and limited exercise capacity. Thirteen people enrolled in the pilot program (mean age 72 ± SD 7 years). A significant improvement in the Short Physical Performance Battery score was observed between baseline and 6-months (MD = 2.01; 95% CI 0.45 to 3.58), and between 3-months and 6-months (MD = 1.65; 95% CI 0.48 to 2.81). The alternate step test improved by more than 3 seconds between baseline and 3-months (MD = −3.30; 95% CI −5.94 to −0.66) and improved by 4 seconds between baseline and 6-months (MD = −4.01; 95% CI −7.42 to −0.61). The program had a high level of acceptability, with all participants intending to continue to do the exercises. The study concluded that the program was feasible to implement and showed promising results, supporting the need for evaluation in a larger trial.

This thesis addresses key gaps in the literature, providing robust evidence for the effectiveness of home-based exercise programs for older adults. This thesis outlines implications for practice and future research. It informs future intervention design and justifies further testing in a fully powered trial for a scalable solution to the issue of falls and upper limb dysfunction, particularly in those who would benefit most from an exercise program, such as those with low initial levels of physical activity, chronic conditions, poor strength and balance, older age and identified to be at a greater risk of falls and upper limb dysfunction and what strategies work best to enhance adherence.

Chapter 1: Introduction

1.1. Authorship contribution statement

As primary supervisor, I confirm that Amanda Macaulay (Bates) authored Chapter One, Introduction. Critical feedback was provided from supervisors Professor Anne Tiedemann and Dr Heidi Gilchrist.

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

1.2. Introduction to the ageing population

1.2.1. Definition of ageing

Ageing is typically defined as the progressive decline in several physiological functions over time, leading to increased vulnerability to diseases and mortality.[1] Healthy ageing is the process of developing and maintaining the functional ability that enables wellbeing in older age.[2]

1.2.2. International context for ageing

Globally, the population is ageing, and this is occurring at a faster pace than in the past.[3] Across the world, every country is experiencing growth in both the size and proportion of older people in the population.[3] The World Health Organization (WHO) predicts that by 2030, 1 in 6 people globally will be aged 60 years and over, and that the world's population will double to 2.1 billion by 2050. It is also predicted that the number of people aged 80 years and over will triple between 2020 and 2050 to reach 426 million.[3]

1.2.3. Australian context for ageing

Australia's population is ageing, mirroring the global trend, with 1 in 6 Australians currently aged 65 years and over. The Australian Institute of Health and Welfare (AIHW) defines an older person as a person aged 65 years and over.[4] Australians aged 65 years and over accounted for 16% of the population in 2020, an increase from 8.3% in 1970. Furthermore, by 2071, Australians aged 65 years and over will make up 25% of the population, while those aged 85 years and over will account for 5% of the population.[5] In Australia in 2021-2023, life expectancy at birth was 81.1 years for males and 85.1 years for females, while the health-adjusted life expectancy lower at 71.7 and 73.8 years respectively, reflecting a substantial period lived with illness and/or disability.[6] These averages also mask inequalities, with

individuals in the most socioeconomically disadvantaged areas experiencing significantly shorter lives compared to those in the most advantaged areas, with the differences of approximately 6-7 years for men and 4-5 years for women.[6-8] Socioeconomic disparities are also displayed in health-adjusted life expectancy, with lower socioeconomic groups not only living fewer years overall but also spending a greater proportion of life in poor health. Analyses from the Australian Institute of Health and Welfare show that the burden of chronic disease, disability, and modifiable risk factors is disproportionately higher in disadvantaged populations, contributing to both reduced longevity and reduced health-related quality of life.[7] These inequities intersect with other forms of disadvantage, including Indigenous status and geographic remoteness. For example, Aboriginal and Torres Strait Islander Australians have a life expectancy approximately 8–9 years lower than non-Indigenous Australians, alongside lower health-adjusted life expectancy, further illustrating the compounding effects of social and structural determinants of health.[6-8] Australians have a higher life expectancy than many comparable countries, including New Zealand, the United Kingdom, the United States of America, and Canada.[6]

The setting of the current study is in the Illawarra and Shoalhaven regions of New South Wales, Australia. The Illawarra and Shoalhaven regions are a mix of coastal, urban and rural lifestyles, concentrating residential areas into a narrow strip along the coast of New South Wales. The region has over 420,000 residents, with 91,000 residents (22%) aged over the age of 65.[9]

The WHO has declared 2021-2030 as the Decade of Healthy Ageing.[10] The Baseline Report for the Decade of Healthy Ageing stresses that optimising functional ability is a key to healthy ageing; and developing and maintaining functional ability enables well-being in older

age.[10] The report presents four action areas to optimise functional ability including: change how we think, feel and act towards age and ageing; ensure that communities foster older people's abilities; deliver person-centred integrated care and services that respond to older people's needs; and provide access to long-term care for older people who need it. Strengthening data, research and innovation is also cited in the baseline report as an enabler to accelerate the implementation of interventions to optimise functional ability and healthy ageing.[10] This thesis hopes to improve and maintain the functional ability of older adults by delivering a home-based exercise program.

1.2.4. Benefits of an ageing population

There are benefits to the global trend of ageing populations that are worth acknowledging. An ageing population can bring wisdom, experience and stability to communities. Older adults often serve as mentors, volunteers, carers, workers and cultural custodians; contributing significantly to the social cohesion and knowledge transfer between generations.[10-13] Evidence shows that their continued workforce participation enhances economic resilience, while their engagement in volunteering and caregiving fosters healthier, more cohesive societies. With one in six people worldwide projected to be aged 60 or over by 2030, harnessing the contributions of older adults is vital for sustaining intergenerational collaboration and cultural continuity.[3,10-12] However, there are also challenges to an ageing population and these will now be explored.

1.2.5. Challenges of an ageing population

While ageing populations bring social and cultural benefits, they also pose significant health and economic challenges. Many disorders appear more frequently in older age and can impact functioning. These include chronic conditions such as, non-communicable diseases,

musculoskeletal disorders and cognitive impairment,[14] which increases demand for long-term care and can strain health systems.[4] Evidence from the AIHW highlights ageing as a major driver of rising healthcare expenditure and aged care demand, with higher use of allied health services and pharmaceuticals and higher rates of primary care visits and hospitalisations than younger people.[4] Many conditions, such as diabetes, cardiovascular disease, musculoskeletal disorders and cognitive impairment, can be prevented or delayed by engaging in healthy behaviours, such as physical activity and healthy eating.[2,14-16]

This thesis focuses on three common conditions that contribute to morbidity and mortality among older adults: falls, upper limb dysfunction, and chronic obstructive pulmonary disease (COPD). These conditions, and the role of physical activity in preventing and managing these conditions, will be explored in detail in sections 1.4 – 1.6 of Chapter One. The role of physical activity for promoting healthy ageing among older adults will now be explored.

1.3. Physical activity for older adults

1.3.1. Physical activity definitions

Physical activity is defined as any bodily movement produced by skeletal muscles that requires energy expenditure.[17] Physical activity can be assessed across multiple domains, including leisure time, occupation, household and transportation.[17] Exercise is a subcategory of physical activity that is planned, structured and purposeful in the sense that the improvement or maintenance of physical fitness is the objective.[17] Exercise generally refers to physical activity that is performed within leisure time with the primary purpose of improving health and/or physical fitness.[17]

1.3.2. Benefits of physical activity for older adults

Physical activity is essential to maintaining good health and wellbeing at all life stages. Maintaining healthy behaviours throughout life, including engaging in regular physical activity, contributes to improving physical and mental capacity, reducing the risk of non-communicable diseases, promoting independence and delaying care dependency.[3] Regular physical activity is one of the most widely recognised ways to attenuate physical and cognitive decline often associated with ageing,[18] providing physical, psychological and social benefits.[19]

1.3.3. Physical activity recommendations for older adults

The WHO Guidelines on Physical Activity and Sedentary Behaviour recommend that older adults should engage in 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity aerobic activity, and for additional health benefits older adults should perform muscle strengthening activities on at least two days per week and functional balance and strength training on three or more days per week.[17] The WHO Global Action Plan on Physical Activity 2018-2030 states that older adults can benefit from regular physical activity to maintain physical, social and mental health, prevent falls and realise healthy ageing.[20] Strengthening the provision of, and access to appropriate opportunities and programs can enable all older adults to maintain an active lifestyle according to capacity.[20]

The 2025 international consensus on exercise for older adults provides optimal exercise recommendations for enhancing healthy longevity in older adults.[18] It notes that resistance, aerobic, balance and mobility training can specifically target age-related deficits, and that despite the multiple benefits of exercise, its incorporation into medical practice for older adults remains limited.[18] This consensus provides the reasoning for the incorporation of

physical activity into health promotion, disease prevention and management strategies for older adults.

1.3.4. Consequences of physical inactivity among older adults

Physical inactivity has been identified as the fourth leading cause of death worldwide.[21] Physical inactivity has also been recognised as a global pandemic,[21] with data suggesting that up to one-third of the global population is not meeting the recommendations for physical activity.[22] More than half of Australian adults do not meet the recommended guidelines for physical activity.[23] Levels of activity tend to decline with older age, with only one in three men and one in five women aged 75 years and over undertaking sufficient physical activity.[23]

The impact of physical inactivity as a risk factor for chronic disease is significant.[24] Disease burden measures the health loss from living with, or dying prematurely from, a disease or injury.[24] It has been estimated that physical inactivity is responsible for 2.6% of the total disease burden in Australia. However, when physical inactivity is combined with overweight and obesity, the burden increases to 9%, equal with tobacco smoking which is the leading risk factor for disease burden in Australia.[24] Physical inactivity was found to contribute to substantial proportions of the disease burden in the following diseases: 19% for diabetes, 16% for bowel cancer and 16% for uterine cancer, 14% for dementia, 11% for coronary heart disease and 11% for breast cancer and 10% for stroke.[24] Physical inactivity increases the risk of a range of diseases including cardiovascular disease, type 2 diabetes, cancer and dementia.[25-27] Further, Australians in the most socioeconomically disadvantaged group experienced rates of disease burden due to physical inactivity at 1.7 times that of the highest socioeconomic group.[24]

1.3.5. Barriers and facilitators to physical activity among older adults

There are many barriers and facilitators to participating in physical activity for older adults, which vary according to age, functional ability, geographical location and gender.[28-31] Identifying the common barriers and facilitators is crucial to developing effective strategies to increase participation in physical activity among older adults.

Franco et al[28] conducted a systematic review and thematic analysis of qualitative literature to understand older people's perspectives on barriers and facilitators to participation in physical activity. Major themes reflecting older people's perspectives on physical activity were identified, these included physical limitations, competing priorities, access difficulties, personal benefits of physical activity, social influences, and motivation and beliefs. Franco et al identified that some older adults continued to view physical activity as unnecessary or even risky, while others appreciate the benefits but encounter multiple barriers that limit their participation. The review synthesised evidence from a large, international sample. The included studies were predominantly conducted in high-income, Western countries, such as the United Kingdom, United States of America, Australia and parts of Europe, with more limited representation from low- and middle-income settings. While some cultural diversity and socioeconomically disadvantaged groups were included, these were not comprehensively represented across studies. As a result, the findings are most transferable to community-dwelling older adults in high-income contexts, with more limited generalisability to populations in different cultural or socioeconomic settings. To increase participation among older adults, efforts should focus on both promoting understanding of the health gains and reducing fears about harm, and on making opportunities to be active more accessible by addressing environmental and cost barriers.[28]

Kilgour et al reviewed the quantitative evidence on barriers and motivators for physical activity in adults aged 70 years and over, using 37 studies and nearly 27000 participants from high income countries.[29] Similarly, the frequently reported barriers included health and fitness concerns (symptoms, poor perceived fitness, belief that activity may worsen problems), low motivation, fear of falling and environmental barriers. Key motivators were support from family and friends, opportunities for social interaction, perceived personal benefits and access to nearby facilities.[29]

1.3.6. Physical activity interventions for older adults

Regular physical activity is important for preventing disease and also in managing chronic diseases.[32] Because of the known benefits of physical activity, and the risks associated with physical inactivity, governments and health services have made considerable effort to support people to be more active by implementing interventions and services targeting different populations.[33] A review of long-term physical activity interventions for older adults found they were safe and effective, with the benefits appearing to be independent of the participants' age, physical function or cognitive status at baseline.[34] Physical activity interventions for older adults lead to a lower risk of falls and fall-related injuries and improvements in physical function, muscle strength, balance and cognition.[34,35] Importantly, as well as increasing function, long term physical activity interventions do not increase older adults' risk of morbidity or mortality when compared with those not participating in the intervention, suggesting they are suitable for older adults.[34]

Older adults, within the oldest-old age bracket of aged 80 years and over, have been identified as one of the age groups expected to see significant growth in coming years.[5,36] This age group has been shown to have low adherence to regular physical activity, [37] as well

as greater barriers to participation in physical activity.[36] Therefore there is a need for interventions that promote healthy ageing within this 'oldest-old' age group. There is a well-documented gap in the literature on physical activity among older adults in low- and middle-income countries, with existing evidence largely derived from high-income settings and limited representation of low-income or underserved populations, thereby constraining the generalisability of findings to these contexts.[38]

1.3.7. Home-based exercise programs for healthy ageing

Community-based group exercise programs have typically been offered as a more traditional form of exercise for healthy ageing. However, sustained adherence to community exercise is a challenge with many people becoming less physically active as they age.[39] Traditional group-based exercise programs, while effective in improving physical function in older adults may not be suitable, accessible or preferable to all older adults.[40] As such, home-based exercise programs have emerged as a viable alternative to traditional centre-based or supervised group-based exercise programs, particularly among older adults.

Recent systematic reviews and meta-analyses provide strong evidence for the effectiveness of home-based exercise programs in improving physical function in older adults. [36,40-42] Costa et al[40] reviewed 11 randomised controlled trials (RCTs) (n=1219) and observed that home-based exercise programs improved gait, balance, muscle strength, and mobility in older adults when compared to control groups. When compared with supervised exercise programs, the results were similar for gait, balance and mobility but the supervised programs showed a greater improvement in muscle strength. However, when additional levels of supervision were provided in home-based exercise programs (via group sessions, home visits or telephone calls), there were enhanced balance and strength outcomes. Higher supervision within home-

based exercise programs could provide substantial benefits to the program outcomes.[40] This finding was also supported by a 2013 systematic review by Geraedts et al which found that home-based exercise programs with frequent remote feedback in the form of phone calls improved physical measurements similar to supervised programs.[42]

A systematic review (34 RCTs, *n*=2830) by Gomez-Redondo et al compared the safety, adherence/attendance and effectiveness of supervised versus unsupervised exercise on physical function and well-being measures in older adults.[41,43] Similar to Costa et al,[40] there were greater gains in strength for supervised exercise compared to unsupervised exercise.[41] There was no difference in safety between the supervised and unsupervised exercise programs, indicating that home-based is a safe alternative for older adults who would prefer to exercise in their own home. The authors concluded that sustained adherence to exercise is required in order to acquire and maintain the benefits associated with participation, and unsupervised exercise programs show similar rates of attendance compared to supervised programs.[41]

A scoping review of 20 studies (*n*=1796) conducted by da Silva Capanema et al[36] on home-based exercise programs for people aged 80 years and over with physical frailty found that home-based exercise programs provided significant increases in overall physical performance including muscle strength, balance, gait speed and flexibility. All of which have the potential to improve the quality of life and independence of older frail adults. They found that adherence was high in the majority of programs (72%-89%) indicating that exercising at home is a well-accepted approach for many older adults with physical frailty.[36] This scoping review also found home-based exercise to be safe for adults aged 80 years and over.[36]

Physical activity strategies for older adults need to go beyond education about health benefits of exercise and focus on improving access to exercise programs. It appears that older adults place greater value on the characteristics of the exercise program rather than the actual benefits. Franco et al[44] identified that the type of exercise, travel time and costs may be more highly valued by older adults than the health benefits. Exercise that can be undertaken at or close to home without any cost is most likely to be taken up by older adults with past falls and/or mobility-related disability.[44]

Home-based exercise programs provide many advantages compared to supervised or group-based exercise programs due to ease of participation.[40] Home-based programs eliminate transportation barriers and provide flexible scheduling to accommodate for individual preferences, responsibilities and limitations. This accessibility is particularly important for older adults with mobility limitations, caregiving responsibilities, or those living in regional areas. Home-based exercise programs reduce costs associated with classes and transportation to get to programs.[45,46]

Home-based exercise has the potential to be more sustainable long-term, without the reliance on a program that may only be offered for a limited period of time. During home-based exercise programs participants are able to exercise at their own pace and modify activities as necessary.[40] Participants learn the skills and habits, and are able to integrate regular exercise into their daily routine.[47] Home-based exercise programs can also be complementary to a group-based exercise program to assist older adults to participate in a higher dose of exercise in accordance with the recommended guidelines for physical activity.[17,48] Home-based exercise programs can be cost-effective to both the individual and health care systems, requiring lower resource investment compared to centre-based programs.[49] There is also

minimal cost to the participants, in terms of reduced travel costs and ongoing membership or access fees.[49]

An older person's preferred mode of exercise can vary, making a variety of options important.[50] Individual programs that are carried out at home have been reported to be more appealing to some older adults due to their accessibility, lower cost and greater convenience, particularly for those who are unable to leave home.[44,46] People who are older and at a higher risk of falls are more likely to prefer home-based exercise programs compared to group-based classes.[46,50] Yardley et al conducted a survey of over 5000 people to assess willingness to participate in strength and balance training.[46] The results showed that over 60% of respondents would consider strength and balance training at home. Of these, 36% would definitely do strength and balance training at home, 23% would definitely attend group sessions. The results of this survey indicated that home-based exercise had the widest appeal and is also more appealing to those who are older, have had recent falls and are from lower socioeconomic groups. It was concluded that health promotion programs should promote home-based strength and balance training as a way of encouraging more older adults to engage in exercise for falls prevention.[46] Practical barriers to participation were identified by participants such as time, cost and lack of transportation. Poor health has also been identified as a barrier to uptake and adherence to group-based sessions.[31,45]

Accessibility to exercise programs is important to increase uptake and adherence to exercise programs among the older population.[44] Barmentloo et al[50] described the personal preferences of older adults regarding fall prevention exercise programs. They found that preferences for fall prevention exercise programs can vary widely among older adults, with 49% of participants preferring to exercise at home versus elsewhere, 46% preferring to exercise

individually versus 44% in a group, and 41% wanting to participate in exercise free of charge versus 51% willing to pay to exercise.

1.3.8. Links to Health Promotion theory

Home-based exercise programs are grounded in theoretical frameworks such as the Social Cognitive Theory, which emphasises self-efficacy and environmental factors in behaviour change;[51] and the Ecological Model, which recognises that physical activity behaviours are influenced by multiple factors including individual, social and environmental determinants.[52] Bringing both the Social Cognitive Theory and Ecological Models together, effective home-based exercise programs start with building self-efficacy through simple, achievable tasks and visible progress, while also reshaping expectations about the benefits of exercise.[53] The use of goals, plans and monitoring to provide support in performing home-based exercise are essential. Addressing barriers and enablers by providing equipment, modifying environments and providing check-ins can assist in supporting older adults to engage in home-based exercise.[54]

The Social Cognitive Theory provides a strong framework for understanding engagement in home-based exercise, particularly through its emphasis on self-efficacy as a determinant of behaviour.[51] Evidence shows that self-efficacy is consistently associated with physical activity participation, functional performance, and functional limitations in older adults.[55] Higher exercise self-efficacy predicts both the initiation and long-term maintenance of physical activity.[56] Successful activity experiences strengthen efficacy beliefs through mastery, modelling, social persuasion, and interpretation of physiological cues.[56] A 2025 systematic review and meta-analysis found a significant positive correlation between exercise self-efficacy and physical activity.[55] Interventions incorporating graded task progression,

feedback, and opportunities for successful performance can enhance self-efficacy, which in turn supports greater adherence and improved functional outcomes.[55] While self-efficacy is not the sole factor influencing long-term behaviour, it is a factor influencing physical activity engagement in later life.[57]

The Ecological Model complements Social Cognitive Theory by recognising that physical activity behaviour is shaped by influences operating at multiple levels, including individual, interpersonal, organisational, community and policy domains.[58] Evidence in older adult populations shows that factors such as home layout, neighbourhood walkability, access to equipment, and supportive social networks are associated with physical activity participation and functional outcomes.[52,59,60] Rather than limiting intervention design, an ecological approach strengthens the relevance of home-based exercise programs by encouraging strategies that address real-world barriers and facilitators. This may include modifying the home environment, providing access to equipment, or facilitating social support. This ecological framing aligns well with the personalised nature of home-based exercise and may enhance feasibility.[58]

Integrating Social Cognitive Theory with ecological approaches enhances the effectiveness of home-based exercise programs by combining behaviour change techniques (e.g. goal setting, action planning, self-monitoring) with environmental and social supports. Evidence from behavioural science indicates that self-regulation strategies mediate the relationship between self-efficacy and physical activity, and that supportive environments further strengthen these effects.[60] In older adults, interventions that embed self-efficacy-enhancing strategies within enabling environments, such as regular check-ins, accessible equipment, and social encouragement demonstrate improved adherence, functional performance, and reduced

functional limitations.[61] This integrated approach provides a strong theoretical rationale for the design of home-based exercise programs.

Given the strong theoretical grounding and potential for safety and accessibility, home-based exercise programs to target impairments and disability among older adults are the focus of this thesis. The provision of home-based exercise programs is likely to facilitate participation in physical activity in older adults. In particular, for groups such as those who are older, with chronic disease, at high risk of falls, those who are caring for another individual, people from lower socioeconomic groups and rural and regional areas. Strategies are needed to increase the reach of home-based exercise programs and ensure that they are tailored to the specific needs of the group.

1.4. Falls among older adults

1.4.1. Definition of falls

A fall is defined as 'an unexpected event in which a person comes to rest on the ground, floor or lower level'.[62] Falls in older adults are a significant and increasing public health issue. In Australia, falls are the leading cause of injury-related hospitalisation, and fall-related injury is a leading cause of morbidity and mortality for older adults,[63] with 17 older Australians dying each day as a result of falls,[64] In New South Wales (NSW), more than 25% of people over the age of 65 years fall at least once each year. [65] In 2021 there were 41,600 older people in NSW hospitalised because of a fall, and by 2041 this is expected to increase to over 60,000 older adults in NSW hospitalised yearly because of a fall.[66]

1.4.2. Consequences of falls

Falls are one of the most common causes of injuries among older adults.[67] Each day over 100 people aged 65 years and over are admitted to NSW hospitals after a fall.[66] There have been steady increases in the number of falls in NSW over the past decade. A single fall can significantly alter the health status and quality of life of an older person. Consequences of falls include death,[64] serious injury,[65] fear of falling,[68] reduced quality of life,[69] hospitalisation or entry to residential aged care.[63] With increasing longevity globally, the health burden and related costs associated with falls are expected to increase.[66]

1.4.3. Risk factors for falls among older adults

Falls in older adults are multifactorial, including intrinsic factors like age-related physical decline, chronic conditions and medications; and extrinsic factors such as environmental hazards. Evidence from systematic reviews and meta-analyses identify key risk factors such as advanced age, female gender, history of previous falls, balance disorders, visual impairment, depression, cognitive impairment, fear of falling, muscle weakness, gait problems, polypharmacy and frailty.[70-72]

1.4.4. Exercise for preventing falls

There is strong evidence that exercise can reduce the risk of falls. A 2020 systematic review confirms previous findings that exercise can prevent falls in older adults.[73] This review provided high-certainty evidence that exercise programs can reduce the rate of falls in older adults in the community by nearly 25%.[73] The most effective exercise programs are those that primarily include balance and functional exercises.[73,74]

In light of the strong evidence for exercise to reduce falls, the 2022 World Guidelines for Falls Prevention and Management for Older Adults recommend exercise programs for fall prevention among community-dwelling older adults that include balance challenging and functional exercises. Ideally, these programs should be offered with sessions three times or more weekly and are individualised, progressed in intensity for at least 12 weeks and continued longer for greater effect.[75] Furthermore, the WHO Guidelines on Physical Activity and Sedentary Behaviour recommend that older adults do functional balance and strength training on three or more days per week, to enhance functional capacity and prevent falls.[17]

Best practice guidelines for preventing falls and harm from falls among older people in Australia were released in 2025.[63] The guidelines recommend that all older adults living in the community should undertake 2-3 hours of exercise per week to prevent falls.[63] This exercise should be ongoing and primarily target balance and mobility, including strength training.[63] Older people at low risk of falls (that is, less than one fall per year) should attend community exercise or participate in home exercise, while those at an increased risk of falls (1+ falls per year) should be provided with tailored exercise programs, with supervision or assistance from a health or fitness professional.[63] However, the low rates of participation in effective fall prevention exercise in both the general population and groups at higher risk of falling highlights a clear need for strategies to promote uptake and ongoing participation in exercise programs with balance and strength components that are easily accessible to all older adults.

Many older adults do not meet the exercise recommendations to prevent falls.[76] According to a survey of 5681 older adults in NSW, Australia, only one in eight respondents (12%) participated in strength training and 6% participated in balance training in the previous week;

and only 2% participated in both strength and balance training at the recommended level to prevent falls. It was also identified that older adults who had problems with walking or used a walking aid, and those who had fallen more than twice in the past year, were 20-40% less likely to participate in any balance challenging or strength activities.[76] People aged 75 years and over and carers were also identified as being less likely to participate in regular balance challenging activities.[76]

1.5. Upper limb dysfunction among older adults

1.5.1. Definition of upper limb dysfunction

Upper limb dysfunction is a term referring to any impairment or limitation in the normal function of the upper limb, including the hand, wrist, arm and shoulder. It encompasses musculoskeletal, neurological or soft tissue problems that cause pain, stiffness, weakness, loss of range of motion, resulting in impaired ability to perform daily activities.[77,78] This thesis is focused on upper limb dysfunction resulting from shoulder problems. The most frequent diagnoses in people with shoulder pain are rotator-cuff tendonitis, subacromial pain syndrome, adhesive capsulitis and acromioclavicular joint disorders.[79] However specific diagnoses of shoulder pain are not always straightforward with no clearly defined pathology or physical signs and may also be the result of coexistence of multiple pathologies, and have therefore been termed as non-specific shoulder pain.[80,81] Shoulder pain is the third most common musculoskeletal disorder in adults,[82] after back and neck pain.[83] The prevalence of shoulder pain increases with age,[84-86] with approximately 13-26% of adults aged 70+ years experiencing shoulder pain at any given time (point prevalence).[87]

1.5.2. Consequences of upper limb dysfunction

Upper limb dysfunction, in particular shoulder pain and stiffness, is a major health issue for community-living adults aged 65+ years.[88] Hill et al conducted a survey to determine the prevalence of shoulder pain in a population-based sample.[86] They also explored the associations of shoulder pain and measured the impact of shoulder pain on physical function, range of movement and quality of life.[86] In this survey females and older adults had the greatest burden of shoulder disease, with females 40% more likely to report shoulder pain and/or stiffness than males, and an increased level of shoulder pain and/or stiffness associated with increasing age. Participants reporting shoulder pain and/or stiffness were more likely to have depressive symptoms and lower quality of life scores. Increased age was associated with worse shoulder function, which has implications for independence in older age groups.[86]

Shoulder pain can create a significant burden on individuals and the community by reducing an individual's capacity to participate in work (paid and volunteer), recreational activities and activities of daily living.[80,83] Reduced shoulder flexibility also increases the risk of losing social independence in older adults.[89]

Upper limb dysfunction in older adults, as a result of reduced shoulder movement, significantly reduces daily physical activity, demonstrated by a significant reduction in daily steps while wearing a shoulder orthosis.[90] Shoulder immobilisation also impairs balance in older adults, with a study showing a significant reduction in balance ability in community-dwelling people aged 65 years and over wearing shoulder immobilisers.[91] A study from the Baltimore Longitudinal Study of Ageing highlights the emerging understanding that shoulder dysfunction is significantly associated with mobility limitations in older adults.[92] Restricted shoulder range of motion (ROM) was found to be associated with poorer performance on

lower limb function tests and walking endurance.[92] Older adults with reduced or abnormal ROM were 2.5 to 4.5 times more likely to exhibit poor mobility, even after adjusting for age, sex, weight, height and chronic conditions.[92]

As the Australian population is ageing rapidly,[5] and the greatest burden of shoulder symptoms occurs in older adults, this has implications for health care costs and systems into the future. Therefore, attempts to reduce or prevent the occurrence of shoulder dysfunction in older adults could have broader implications for physical activity, mobility, balance and falls. The role of exercise to improve shoulder dysfunction will now be explored.

1.5.3. Risk factors for shoulder dysfunction

There are multiple risk factors for shoulder pain and dysfunction among adults, including obesity, diabetes, depressive symptoms, physical workload and age-related changes.[93-98] Obesity and increased body mass index consistently raises the risk of shoulder pain and/or stiffness possibly due to mechanical strain and effects from adipose tissue.[98] Elevated risk in older age reflects degenerative joint changes; and physical work, in particular overarm use or heavy lifting show increased pain and stiffness.[97] Lifestyle factors such as smoking, obesity and a sedentary lifestyle were associated with increased prevalence of shoulder pain and/or stiffness.[86]

1.5.4. Exercise to improve shoulder dysfunction

Exercise is commonly used to treat shoulder disorders,[83,99] with moderate evidence from systematic reviews supporting its efficacy.[100-103] A systematic review by Pieters et al stated that the evidence for exercise as the most important strategy for shoulder pain is increasing

and strengthening.[102] Strengthening exercises in multiple planes of motion focusing on strength and stability of the shoulder joint have been recommended.[80,104,105]

A 2024 meta-analysis (54 RCTs, *n*=3893) concluded that shoulder specific exercise therapy is effective in reducing chronic shoulder pain in adults.[106] Shoulder specific exercises were found to be more effective in decreasing pain and maintaining pain relief compared to usual care.[106] Additional adjunct therapies did not provide benefit. Silveira et al acknowledged that exercise therapy should be used as the first line of treatment in managing chronic shoulder pain.[106] Strengthening exercises have been shown to produce small changes in pain but not function or range of motion in non-specific shoulder pain.[80]

A 2024 scoping review summarised the frequency, intensity, time and type (FITT) components of exercise programs for managing shoulder pain. The review included 46 exercise programs from 22 trials and highlighted significant variability in the parameters used to prescribe exercises for shoulder pain.[107] The frequency ranged from 2 to 7 sessions per week. The intensity (load and repetitions) varied from low to high load, with sets ranging from 1 to 3 and repetitions from 4 to 30. The program duration ranged from 4 to 16 weeks with recommendations suggesting at least 12 weeks to determine effectiveness.[107] Few studies focus on the prevention of shoulder dysfunction before symptoms escalate.[107] Further research is needed to determine if there is an optimal dose and type of exercise for the treatment of shoulder pain and dysfunction among older adults. Research is also needed to understand strategies to manage shoulder dysfunction early. This will build the evidence base to inform effective and scalable exercise programs for older adults. This topic is explored in Chapter Five of this thesis.

1.6. Chronic obstructive pulmonary disease among older adults

1.6.1. Definition of COPD

Chronic obstructive pulmonary disease (COPD) is the collective term for a number of lung diseases that interfere with normal breathing.[108] It is a progressive condition characterised by persistent airflow limitation. Symptoms include breathlessness, wheezing, coughing, fatigue and increased susceptibility to chest infections.[109] There are many causes of COPD including tobacco smoke, genetic disorders and environmental factors such as exposure to air pollution and occupational fumes.[108]

1.6.2. Consequences of COPD

In 2019 COPD was the third most common cause of death globally.[110] It is estimated that the global prevalence of COPD is 10.3%, and this is expected to rise due to ageing of the world's population in high-income countries and increasing smoking prevalence in low- and middle-income countries.[111] In Australia, COPD is the leading cause of avoidable hospital admissions across all age groups.[112] Almost all people with COPD in Australia (87%) in 2022 had two or more chronic conditions.[113]

In high-income countries, COPD disproportionally affects people from rural areas and lower socioeconomic groups.[108,114] In Australia, COPD prevalence is twice as high in areas of highest disadvantage compared with least disadvantage (3.8% vs 1.6%, respectively).[108] In 2018, after adjusting for age differences, the rate of burden from COPD was highest for people living in remote and very remote areas and lowest for people living in major cities (8.5 and 5.2 DALY per 1,000 population, respectively).[108]

Symptoms of COPD are common in adults aged 40 years and over,[115] however older adults represent the largest group affected by COPD,[108,115] with the condition often complicated by multiple co-morbidities and frailty syndromes.[108,116,117] Dyspnoea, or shortness of breath, is the most common symptom of COPD.[118] People with COPD often have a sedentary lifestyle, as many avoid exercising to decrease their breathlessness, which results in reduced fitness and even more breathlessness on exertion.[109] People with COPD have a higher frequency of hospitalisations, which increase as the disease progresses, and an increased length of stay in hospital.[112] They also have an increased rate of co-morbidities, including heart problems, osteoporosis (due to steroid use), chest infections, anxiety and depression.[109]

1.6.3. Risk factors for falls in people with COPD

Physical inactivity is both a consequence and contributor to the progression of COPD. People with COPD demonstrate significantly reduced levels of physical activity compared to healthy individuals.[118] This creates a cycle of deconditioning that worsens exercise tolerance and quality of life.[109,118]

Older adults with COPD are at a higher risk of falls than their healthier peers, due to reduced physical activity, poorer balance, reduced muscle strength and exercise capacity.[119-122] Approximately 30% of adults aged 65 years and over will fall each year.[123] A prospective cohort study has found the fall prevalence to be 40% in people with COPD.[124] Many studies indicate that adults with COPD perform substantially worse than healthy controls on measures of balance and strength.[121,122,125] These impairments are associated with a lower functional capacity and independence and physical inactivity.[122] More severe deficits in balance and mobility are also seen in people with COPD with more severe disease.[126]

Falls and frailty are also commonly associated with COPD.[117,119] Frailty is defined as a multidimensional syndrome that describes a loss of physiological reserves, leading to a reduced ability to recover from stressors such as illness or injury. It is characterised by symptoms like unintentional weight loss, muscle weakness, low energy, and low levels of physical activity. Frailty increases the risk of adverse health outcomes, including falls, hospitalisations, disability and mortality.[117,127] Frailty prevalence has been shown to be higher in people with COPD.[116] Frailty may also identify people with COPD who are at a higher risk of mortality,[116] and frailty can reduce mobility and daily functioning, particularly with worsening respiratory disease.[128]

1.6.4. Exercise for preventing falls in people with COPD

Pulmonary rehabilitation is the most established exercise-based intervention for people with COPD.[129] Pulmonary rehabilitation is a comprehensive, multidisciplinary program that includes exercise training and education, mainly focused on improving pulmonary functioning, exercise capacity and quality of life.[129] Systematic reviews and meta-analyses consistently demonstrate the benefits of exercise interventions for people with COPD,[121,130,131] including improvement in exercise capacity, physical function, reduced dyspnoea and improved psychological wellbeing.[131]

Pulmonary rehabilitation is traditionally delivered as a face-to-face program at a hospital or healthcare facility.[132] Despite this strong evidence, very few eligible people attend or complete pulmonary rehabilitation.[132] In Australia, only 5–10% of patients with moderate to severe COPD had accessed pulmonary rehabilitation services and access is difficult in rural settings.[129] Although low rates of uptake and completion of pulmonary rehabilitation have also been reported in metropolitan areas.[133]

COPD guidelines recommend regular physical activity, mainly cardiovascular exercise in the form of walking, but have also recently changed to include muscle strengthening exercises twice a week, as well as noting balance exercises would be beneficial.[134] Delbressine et al[125] conducted a systematic review of exercise interventions on fall risk and balance in patients with COPD. Exercise interventions were shown to have a positive effect on balance in patients with COPD. Pulmonary rehabilitation combined with balance training appeared to show the most beneficial effect on balance.[125] However, it is currently unclear whether these interventions also reduce fall risk.[125] Therefore, further research is needed to determine how exercise may reduce the risk of falls in older people with COPD. This topic is explored in Chapter Six of this thesis.

1.7. Aims of the thesis

Regular, targeted, physical activity can facilitate healthy ageing by maintaining strength and balance in order to reduce falls, as well as aid in the management of chronic conditions such as shoulder dysfunction and COPD. While traditional approaches to prevent and manage these conditions have often been group based, home-based exercise programs can promote wellbeing and independence in older age and improve access to physical activity for those unable to attend group-based exercise programs. However, critical information such as the optimal type and dosage of home-based exercise programs for these conditions is lacking, along with interventions that are able to be implemented at scale for community-dwelling older adults. Therefore, the overall aim of this thesis is to investigate new implementation approaches, in terms of set up and delivery, for home-based exercise programs for older adults. The research methods used to address this aim were a large scale randomised controlled trial (Chapters Three and Four) and a pre and post pilot study (Chapter Five).

The specific objectives were to:

1. Summarise the evidence for the effectiveness of home-based exercise interventions (Chapter Two), in relation to:

a) preventing falls in older adults in the community

b) reducing upper limb dysfunction, and

c) preventing falls in adults with COPD

2. Describe the design and methods of a home-based exercise intervention for older people (Chapter Three)
3. Conduct a large scale randomised controlled trial to investigate the impact of a home-based exercise program for the lower body on falls, fear of falling and physical function among older people (Chapter Four).
4. Conduct a large scale randomised controlled trial to investigate the impact of a home-based exercise program for the upper body on upper limb function, strength and mobility among older people (Chapter Five).
5. Conduct a pilot study to determine the acceptability, feasibility and potential effect of a home-based exercise program for people with COPD accessing a virtual care service (Chapter Six).

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Chapter 2: What is the evidence for home-based exercise programs for preventing falls and upper limb dysfunction in older adults?

2.1. Authorship contribution statement

As primary supervisor, I confirm that Amanda Macaulay (Bates) authored Chapter Two, What is the evidence for home-based exercise programs for preventing falls and upper limb dysfunction in older adults?

Critical feedback was provided from supervisors Professor Anne Tiedemann and Dr Heidi Gilchrist.

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

2.2. Preamble to Chapter Two

Understanding the evidence is an important first step in testing new delivery models for home-based exercise in older adults. This chapter summarises the current literature for the effectiveness of home-based exercise interventions in relation to:

a) preventing falls in older adults in the community
b) reducing upper limb dysfunction, and
c) preventing falls in adults with COPD

The summary sought to understand efficacy and adherence of interventions, and to identify evidence gaps for home-based exercise programs for older adults.

2.3. Background

Chapter One outlined the problem of physical inactivity for older adults in the context of three health burdens: falls, shoulder dysfunction and chronic obstructive pulmonary disease (COPD). A brief overview of the evidence for management of these conditions using exercise therapy, in particular home-based exercise programs, was also explored. In this Chapter Two, a deeper examination of the evidence for home-based exercise programs will be explored for both falls and shoulder dysfunction.

2.4. Research questions

The overarching research question for this Chapter Two is 'What is the evidence for home-based exercise programs for preventing falls and upper limb dysfunction among older adults?' Specific questions to be answered include:

- What is the effectiveness of home-based exercise programs for preventing falls among older adults?
- What is the effectiveness of home-based exercise programs for improving physical function, balance and strength among older adults?
- What is the effectiveness of home-based exercise programs for preventing falls among specific population groups?
- What is the cost-effectiveness of home-based exercise programs among older adults?
- What are the characteristics of successful home-based exercise programs for preventing falls and managing shoulder dysfunction among older adults?

- What is the effectiveness of home-based exercise programs on preventing shoulder dysfunction among older adults?
- What is the effectiveness of home-based exercise programs for preventing falls among older adults with COPD?
- What is the adherence to home-based exercise programs among older adults?
- What are the key gaps in the literature regarding home-based exercise programs targeting falls and shoulder dysfunction in older adults?

2.5. Evidence for home-based exercise in preventing falls

Home-based exercise interventions have emerged as a promising strategy for preventing falls in older adults, offering autonomy, accessibility, flexibility and cost-effectiveness.[1,2] Home-based exercise programs are performed, unsupervised, at home or other informal places, and are indirectly supervised only periodically to adjust the exercise load.[3] Traditional fall prevention strategies have focused on group- or centre-based exercise sessions that are directly supervised by an exercise trainer or health professional.[3] However, there are numerous barriers to supervised programs including transportation difficulties, mobility limitations, caring responsibilities, cost and volunteer and work commitments.[1,4,5] Home-based exercise programs have the potential to reduce or overcome these barriers. Therefore, home-based exercise programs have become a suitable and effective approach for improving strength, balance, gait and physical function in older adults.[6,7]

Multiple systematic reviews and meta-analyses have demonstrated the effectiveness of exercise interventions for fall prevention.[8-11] A Cochrane review by Sherrington et al[8]

analysed 108 randomised controlled trials (RCT) with 23,407 participants. Exercise was found to reduce the number of falls over by approximately one-quarter (23%). Exercise was also found to reduce the number of fallers by around one-sixth (15%) compared with a control group. The effects were similar whether the trials selected people at a higher risk of falling or not.[8] Both home-based and group exercise programs reduced the rate of falls compared with control conditions, and both formats also reduced the proportion of people who fell at least once, indicating fewer fallers overall compared with non-exercise controls. When sub-group analyses were conducted and trials were grouped by delivery mode, there was no difference in the effect on falls according to whether the interventions were delivered in a group setting or individually prescribed/home-based exercise programs.[9] This indicates that the main factor behind the benefit is the exercise content (especially sufficient balance challenge and dose) rather than whether the program is delivered in a group or at home. There was a greater reduction on the rate of falls from exercises where the interventions were delivered by a health professional (mainly a physiotherapist) than in interventions delivered by trained instructors who were not health professionals, although both did reduce the rate of falls.[9] This may be due to health professionals having more skill in evaluating individual risk factors, functional capacity and exercise tolerance, allowing for more individualised prescription.

An umbrella review conducted by Shafizadeh et al in 2022 was the first to analyse existing systematic review and meta-analysis studies on home-based exercise programs in community-dwelling older adults.[5] The review included 14 studies that were meta-analyses (*n* = 4), systematic reviews (*n* = 2) and mixed (*n* = 8) and included a total of 116,576 participants. Shafizadeh et al also demonstrated that home-based exercise programs are safe for older people and are feasible to implement, with high acceptability and adherence rates

among participants.[5] The authors concluded that home-based exercise programs improve physical function and can reduce falls by 32%.[5] These findings were in agreement with a previous systematic review and meta-analysis of 12 studies which included a total of 2,999 participants, found that individualised home-based exercise programs reduced the number of fallers (except in older people returning home from hospital), and improved physical performance outcomes including balance, leg strength, function and physical activity for older people living in the community.[4] However, the authors recommended that strategies are needed to increase the reach of home-based exercise programs and promote adherence to achieve these positive outcomes.[4]

The Otago Exercise Programme (OEP) is an example of a widely implemented and researched home-based fall prevention exercise program.[12] The program consists of a set of 17 strength and balance exercises which take approximately 30 minutes to complete.[12] The exercises include seated knee extension, standing knee flexion, standing hip abduction, calf raises, toe raises, sit to stand, semi squats from a standing position, tandem stand, tandem walk (forward and backwards), sideways walking, backwards walking, heel walking, toe walking, one leg stand, walking and turning around (figure of 8) and stair walking.[12] The program is implemented via a series of home visits (at weeks 1, 2, 4 and 8) to prescribe and progress an individually tailored exercise program. Between the home visits the exercise instructor telephones the participant every month to check on progress and maintain motivation.[12] The OEP was effective in reducing falls by 35% and had the greatest impact in those aged 80 years and older.[13] A systematic review and meta-analysis was conducted (7 RCTs, total *n*=1503) to evaluate the effect of the OEP on risk of mortality, fall rates, injurious falls and compliance to the exercise program.[10] The OEP appears to reduce fall rates and mortality over 12 months in community-dwelling older people.[10] Positive results were

achieved even with compliance to the program twice per week, rather than the recommended level of three or more times per week.[10] One subgroup analysis looking at those who adhered to the recommended level of three or more times per week and found the rate of falls to be 77% lower in those who exercised at least three times per week compared to those who exercised less than once per week.[10] It is possible that greater effects on balance, strength and reduction in falls is possible with a high level of adherence to the recommended dose of exercise.[10] The OEP has since been successfully implemented, replicated and modified in many different countries around the world including Sweden,[14] Canada,[15] America,[16] Greece,[17] Korea,[18] Iran,[19] Serbia[20] and others. A number of different variations of the OEP have been implemented including group-based, video-based and programs with different duration and/orfrequency.[17,20-23] It has been implemented in various populations including community-dwelling,[15,24] aged-care facilities,[20] patients with stroke[25] and visual impairment.[26]

2.5.1. Home-based exercise programs for improving physical function, balance and strength

Supplementing the known benefits of home-based exercise on the outcome of falls are a number of systematic reviews and meta-analyses that have reviewed the effects of home-based exercise programs for older adults on strength, balance, mobility and physical function.[27-30] Physical function has been identified as a crucial component of healthy ageing,[31] and deficits in balance, strength, physical function and fall efficacy are all recognised markers for predicting fall risk in older adults.[32-34]

Unsupervised exercise programs have demonstrated improvements in physical function among older adults.[28-30,35] Lacroix et al sought to quantify the effects of supervised versus unsupervised balance and/or resistance training programs on measures of balance and muscle strength in older adults (11 studies, *n* = 621, mean age 74 years).[30] Drawing on 11 studies, the authors were able to show small-to-moderate benefits in favour of supervised interventions for all balance and strength outcomes assessed compared to unsupervised exercise. It was recommended that including small amounts of supervised sessions within mainly unsupervised interventions seemed to produce a beneficial effect and should be considered when designing home-based exercise programs.[30] While supervised components appear to confer additional benefits, evidence also supports the value of entirely unsupervised home-based programs. Mahjur et al conducted a systematic review (13 studies, *n* = 1206, mean age 74 years) to determine the effect of unsupervised home-based exercise training compared to a control group on physical functioning outcomes in older adults.[29] The outcome measurements included the timed up and go test (functional mobility), Berg balance scale (balance) and handgrip strength (muscle strength in upper limb). The unsupervised home-based exercise training significantly improved functional mobility (mean difference (MD) -1.4s, $p = 0.02$) and balance (MD 1.8, $p = 0.009$) but not upper body strength (MD 0.6kg, $p = 0.43$).[29] Beyond general home-based exercise, structured programs such as the OEP have been evaluated for their specific effects on physical function.

Wu et al reviewed the effects of the OEP on physical function in older adults (13 RCTs, *n* = 2402, mean age range 69-83 years).[28] To assess the effects of the OEP on physical function, assessments were categorised into those related to balance, lower body strength, upper body strength and mobility. The findings indicated that the OEP produced a significant improvement in lower body strength (MD = 0.93, 95 % CI: 0.31 to 1.55), balance (MD =

0.59, 95 % CI: 0.22 to 0.96), and mobility (MD = -0.59, 95 % CI: -0.95 to -0.22), however there was not a significant improvement in upper body strength (MD = 1.48, 95 % CI: -0.58 to 3.55).[28] All variations of the OEP (home-based, face-to-face, group-based and video-supported) produced improvements in lower body strength, balance and mobility.[28] Further investigation into the video-supported OEP is warranted, given that there were only two studies that used this medium. However, it was noted that video-supported OEP could contribute to better execution of the exercises, resulting in greater effectiveness.[28] This could also be a more cost-effective way to implement and create greater reach. Wu et al suggested further research to assess the long-term effectiveness of the different forms of the OEP and dose and length of time required for effects.[28] Given the demonstrated effectiveness of the OEP, additional research has investigated whether modified delivery formats can further optimise outcomes and provide greater access to older adults living in the community.

Martins et al 2018 conducted a systematic review (8 studies, *n* = 604, mean age 77 years) to determine if modified OEP formats improved balance compared to the original delivery format.[35] The modified formats included additional vestibular exercises, group classes, peer-led, DVD format (both for individual use at home and as a group in a community centre) and augmented reality. The review concluded that all modified formats of the OEP could improve physical function, in particular balance.[35] Modified and varied formats of the OEP are important to meet the diverse needs of older people, including urban versus regional location, confidence using technology and preference for group or home-based. Martins et al were not able to determine which modified format of the OEP is the most effective or as effective as the original OEP, and further research was encouraged.[35]

2.5.2. Home-based exercise programs for preventing falls among specific population groups

Wang and Kim conducted a systematic review and meta-analysis (15 RCTs, total n = 1278) to compare the effectiveness of the OEP on physical function and fall-related outcomes (such as balance, strength, gait and mobility) in both generally healthy older adults and older adults with compromised health.[36] The OEP improved balance, gait and lower limb strength in general older adults, and even greater effects were seen on balance, gait and lower limb strength in older adults with compromised health.[36] It was acknowledged that the lower baseline levels of those with compromised health, such as reduced muscle strength and balance, may account for this greater improvement.[36] The various conditions for older adults with compromised health were analysed collectively, although it is possible that some conditions may vary in terms of intervention effectiveness. Further research on the effectiveness of the OEP in older adults with specific health conditions is indicated, and this thesis explores the feasibility and potential effects of a modified format of the OEP in people with COPD in Chapter Six.

Those experiencing frailty are one sub group of older people at greater risk of falling.[37] Frail older adults have low rates of participation in physical activity[38] and also often have the most barriers to participation in an exercise program.[39] As mentioned in Chapter One, frailty is a multidimensional syndrome that describes a loss of physiological reserves, leading to a reduced ability to recover from stressors such as illness or injury.[40] Cognitive frailty is characterised by concurrent physical frailty and mild cognitive impairment.[41] Cognitive frailty and physical frailty have been shown to be predictors of fall and fall-related injuries in older adults.[41] Older adults with cognitive impairment are often excluded from fall prevention

research but represent a group of people who could benefit from strength and balance exercise for preventing falls.[42,43]

Home-based exercise programs can produce significant improvements in strength, balance, gait speed and flexibility in frail older adults.[39] A home-based exercise program has been shown to reduce the rates of falls among community-dwelling older adults with cognitive frailty. Furthermore, participants with greater adherence significantly improved physical function.[44] Therefore, home-based exercise presents a promising strategy for older adults with frailty, cognitive impairment and cognitive frailty.[43,44]

2.5.3. Cost-effectiveness of home-based exercise interventions to prevent falls

Economic evaluations demonstrate favourable cost-effectiveness ratios for home-based exercise interventions.[45-47] The relatively low delivery costs, combined with reductions in fall-related healthcare utilisation, can results in substantial savings from a healthcare perspective.[47] An economic evaluation of the Otago Exercise Program found cost savings per participant over two years, primarily through reduced hospitalization and emergency department visits.[24] A systematic review of economic evaluations of fall prevention interventions found that three programs were cost saving, including a multifactorial programme targeted at eight fall risk factors, the OEP delivered to people aged 80+ and a home safety program for people recently discharged from hospital. Of these three programs, the OEP provided most favourable cost-effectiveness ratio per fall prevented.[46] It has been noted that targeting the OEP at those at the highest risk (e.g. previous fallers and older age cohorts 80+) can prevent the greatest number of falls at the lowest cost.[46] It was also

recognised that the OEP may have the broadest applicability and therefore provide the best value for government spending.[46]

A 2019 study modelling the impact of different exercise programs for preventing falls among community-dwelling older adults and comparing the cost-effectiveness, found that both group-based and home-based exercise programs generate substantial health gain and are cost-effective for adults aged 65 years and older.[47] However, a home-based exercise program is more cost-effective than the group-based exercise programs (both commercial and peer-led).[47] It was also highlighted that in addition to preventing falls, these exercise programs had the potential to provide many additional health benefits including chronic disease prevention and a reduction in the impact of fear of falling among older people.[47]

2.5.4. Characteristics of exercise programs for preventing falls in older adults

Research identifies several key components of exercise interventions that are important for preventing falls in older adults, which includes a total weekly dose of three hours or more, and the inclusion of balance and functional exercises.[9] There is no difference whether this exercise is either group-based or conducted individually.[48] Programs should be progressive and a minimum of 12 weeks, although longer has been recommended for sustained outcomes.[9]

Shier et al conducted a systematic descriptive review to determine how exercise programs to prevent falls are implemented from the perspective of a health care setting.[49] This qualitative approach included both home-based and group-based exercise programs that sought to understand the program features and implementation barriers and facilitators.[49] Initial face to

face instruction appears to be essential for establishing proper exercise technique and ensuring safety. Most exercise interventions involve between one and three face-to-face sessions (either home visits, individual or group-based) to demonstrate exercises and provide program materials such as exercise equipment (weights, resistance bands) and written materials (illustrated instruction sheets and program manuals).[49] It was noted that adherence could be encouraged through positive reinforcement, which resulted in less attrition, and that primary care providers were important for identifying and referring patients to exercise programs. Having primary care providers identify patients at risk of falls and refer to appropriate exercise programs is therefore recommended as most older adults visit their health care provider once per year.[49]

2.5.5. Adherence to home-based exercise programs to prevent falls

The World Health Organization (WHO) defines adherence as ‘‘the extent to which a person’s behaviour – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider”.[50] While home-based programs may overcome some barriers such as access, transport etc, they may face different challenges which impact adherence, including lack of social support and reduced accountability compared to group-based programs. Adherence is measured in a variety of different ways making the comparison of adherence rates between interventions difficult. Understanding the factors that influence adherence is important however, as lower rates of adherence are likely to limit the benefits obtained from exercise programs.[51]

Adherence to home-based exercise programs that prevent falls has been systematically reviewed by Simek et al.[52] They found that adherence to home exercise programs was low

and may be influenced by program characteristics. Higher rates of full adherence (defined as completion of 100% of prescribed exercises) were found with interventions containing balance or walking exercise, moderate home visit support and exercise led by a physiotherapist. Higher rates of partial adherence (defined as completion of a proportion of prescribed sessions closest to a 50% threshold) were found in interventions including home visit or telephone support and a participant health service recruitment approach.[52] There has been high variability in adherence to home-based exercise programs reported in the literature, ranging from as low as 18% of participants completing all prescribed exercises in their homes for participants with severe visual impairment to participants reporting 100% adherence.[35,49,53] A 2024 systematic review by Gomez-Redondo et al[27] on supervised versus unsupervised exercise for the improvement of physical function and well-being outcomes in older adults found weighted attendance rates of 81% (range 38-100%) for unsupervised exercise programs. This was comparable to the attendance rates reported for supervised exercise programs (81%, range 60-100%).[27]

Adherence to home-based exercise programs is influenced by a range of factors, including program design, personal and psychological characteristics, and the level of support provided.[51,52] Personal factors may also influence rates of attendance for both group-based and home-based exercise programs.[51] Personal factors associated with greater adherence include higher socioeconomic status, better health status and physical abilities. Psychological factors such better cognitive ability and fewer depressive symptoms were also associated with greater adherence.[51]

2.5.6. Summary of home-based exercise programs to prevent falls in older adults

Home-based exercise programs have been shown to produce improvements in balance, strength and physical function comparable to group-based exercise programs. However, models relying on individual home visits are resource intensive and unlikely to be scalable for widespread use among older adults. Modified delivery formats offer a more feasible alternative, though further research is needed to determine the potential for a home-based exercise program to prevent falls in older adults with instruction provided in a group setting. The design, implementation and effectiveness of such a program, delivered via group-based workshops, is explored further in Chapters Three and Four of this thesis.

2.6. Home-based exercise for preventing shoulder dysfunction in older adults

Shoulder pain and dysfunction are common musculoskeletal disorders in older adults,[54,55] causing impaired functional independence and reduced quality of life.[56,57] Age-related changes in the shoulder can create a susceptibility to dysfunction, making preventive approaches increasingly important.[58] The link between shoulder dysfunction and overall mobility limitation is only beginning to be recognised.[59] A 2023 study by Davis has shown that reduced shoulder ROM significantly increased the likelihood of lower limb performance or poor walking endurance in an older population.[59]

Wang and Kim's[36] systematic review and meta-analysis, which examined the effectiveness of the OEP on physical function and strength, found no significant improvements in physical function or upper limb strength among either generally healthy older adults or those with compromised health. Because upper limb strengthening is not a core component of the OEP,

this lack of improvement is not unexpected, particularly given that many older adults experience declines in upper limb strength and mobility.[58] Impaired upper limb strength, commonly assessed by handgrip strength,[60] has been associated with limitations in activities of daily living,[61] slower walking speed,[62] higher rates of premature mortality[63,64] and reduced pulmonary function.[65] In order to improve upper limb strength and overall physical function, Wang and Kim recommended that future research should explore incorporating strength training for the upper limb into the OEP.[36] Therefore, an exercise program to improve upper limb strength, mobility and function in older adults is explored in Chapter Five of this thesis.

2.6.1. Systematic reviews of home-based exercise for shoulder dysfunction

Systematic reviews of interventions for shoulder dysfunction and pain consistently demonstrate that exercise is an effective form of treatment,[54,66-69] with a 2024 network meta-analysis recommending exercise therapy as the first line of treatment in managing chronic shoulder pain.[67] Within this broader evidence base, home-based exercise programs have emerged as a viable and effective option,[66,70,71] showing comparable outcomes to both group-based and individual physiotherapy.[71] This growing body of research provides a strong foundation for understanding of the role of home-based exercise in managing shoulder pain and dysfunction.

Building on the broader evidence that exercise is an effective first-line treatment for shoulder pain, several systematic reviews provide more detailed support for the role of home-based exercise programs. Abdulla et al[71] reviewed five RCTs (n=466) investigating the effectiveness of exercise for the management of subacromial impingement syndrome and other soft tissue injuries of the shoulder. Subacromial impingement syndrome is a widely

accepted term for a number of possible structural or biomechanical causes of shoulder dysfunction,[72] and has been proposed as the most common source of shoulder pain,[73] accounting for nearly half of all consultations for shoulder pain in primary care.[74] Their findings showed that both supervised and home-based exercise, incorporating progressive shoulder strengthening and stretching exercises for the rotator cuff and scapular muscles, are effective options for the management of subacromial impingement syndrome of varied symptom duration.[71] In longer term subacromial impingement syndrome lasting greater than three months, both home-based and supervised strengthening exercises produced comparable outcomes on pain, disability, strength and function, not only to each other but also to surgical intervention followed by rehabilitation.[71] This highlights the therapeutic value of exercise irrespective of delivery format. The authors concluded that more research is needed on short- and long-term effectiveness of exercise in different subgroups of shoulder disorders.[71]

Further reinforcing these conclusions, Gutierrez-Espinoza et al found in their systematic review (7 RCTs, n=371, mean age 49 years) that supervised physiotherapy and home-based progressive shoulder strengthening and stretching exercises were equally effective in patients with subacromial impingement syndrome.[70] Consistent with these findings, more recent evidence has reinforced the effectiveness of home-based exercise across diverse shoulder pain presentations. A 2022 systematic review and meta-analysis of 12 randomised controlled trials (n = 935, mean age range 38-55 years) by Liu et al evaluated the effectiveness of home-based exercise for non-specific shoulder pain.[75] The authors concluded that home-based exercise produces comparable benefits to supervised or clinic-based interventions for reducing pain (MD 0.27; 95% CI -0.12 to 0.65) and improving shoulder function (MD 0.12; 95% CI -0.14 to 0.38). When compared to no intervention, home programs were superior and showed large improvements in pain (MD 1.47; 95% CI -2.33 to -0.61) and function (MD

0.81; 95% CI -1.31 to -0.31). These findings supported home exercise as an effective conservative treatment option for shoulder pain and function.[75] Similarly, these results align with a broader systematic review of conservative treatments on pain, function and range of motion in adults with shoulder impingement (200 trials, *n* = 13791, age range 18-65 years), which confirmed that exercise therapy improves pain, function and active range of motion.[68] Furthermore, shoulder-specific exercises were shown to be more effective than general exercises.[68] Together, these reviews strengthen the argument that targeted home-based exercises can deliver clinically meaningful benefits across a range of shoulder conditions.

Emerging delivery models further strengthen the case for home-based exercise. A 2024 systematic review and meta-analysis of telerehabilitation and home-based exercise (7 studies, n = 508, mean age 57 years)[76] found that both approaches improved pain, ROM, function and quality of life in individuals with shoulder disorders. Telerehabilitation uses communication and information technologies such as text messages, internet-based platforms and videoconferencing to facilitate remote interactions between health care providers and patients. It enables continuity of care and provides flexibility in how interventions are scheduled, progressed and tailored to individual needs. Whereas, home-based exercise involves patients performing exercises at home without real-time therapist supervision, relying on prior instructions. Telerehabilitation produced greater improvements in ROM, function and quality of life than home-based exercise.[76] Telerehabilitation and home-based exercise provided comparable outcomes in pain relief for interventions less than 12 weeks, however telerehabilitation became superior when programs continued beyond 12 weeks.[76] These findings suggest that home-based exercise remains an effective option, with telerehabilitation offering an enhanced alternative when additional support or monitoring is desired. Taken together, these systematic reviews provide consistent and compelling evidence

that home-based exercise offers an effective, accessible and scalable approach to managing shoulder pain and dysfunction.

2.6.2. Randomised controlled trials of home-based exercise for reducing shoulder dysfunction

The previous section outlined the Level I evidence supporting the role of home-based exercise in managing pain and function in people with shoulder dysfunction. Evidence from randomised controlled trials reinforce the role of home-based exercise as an effective and feasible intervention for shoulder dysfunction. These will now be reviewed to explore specific parameters and contextual factors for successful exercise programs.

A 2021 RCT involving 208 patients (mean age 52) with subacromial pain compared group-based exercise rehabilitation, individual exercise rehabilitation and home exercise rehabilitation for a period of eight weeks and found that all three formats produced similar improvements in pain and physical function.[77] The primary outcome was assessed by the shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire (Quick-DASH), which measures physical function and symptoms related to upper limb disorders. Similar beneficial effects were observed for the secondary outcomes of quality of life, pain intensity, fear avoidance, psychological wellbeing and participant perception of improvement. Notably, the home exercise intervention was the most cost effective option.[77] These findings align with those of Granviken and Vasseljen, who also reported comparable improvements in in pain and disability between supervised and unsupervised home exercise in people with subacromial pain when working at the same training dose.[78] Consistent with these individual

trials, recent systematic reviews and meta-analyses conclude that home-based exercise alone may be equally effective as other conservative treatments for non-specific shoulder pain.[71,75]

Additional RCT evidence supports the value of home-based exercise even when delivered with minimal supervision. Santello et al conducted a RCT (n = 60, mean age 54) on the effect of teaching patients with shoulder pain how to undertake a home-based exercise program while waiting for physiotherapy treatment while the control group received minimal education about their shoulder condition and were instructed to continue their usual activties.[79] The primary outcome was measured by the Shoulder and Disability Index (SPADI). After two months, shoulder function improved (40 points on the SPADI) and pain decreased in the intervention group (3.7 points on the pain rating scale).[79] This suggests that home-based exercise programs could serve as an effective early intervention within public health systems, reducing symptom burden during waiting periods.

Innovative delivery models further highlight the adaptability of home-based exercise. Maenhout et al conducted a pilot study in adults with chronic shoulder pain to determine the effectiveness and feasibility of a novel home-based exercise program implemented via telerehabilitation.[80] Twenty-six patients with chronic shoulder pain participated in a home-based exercise program for six weeks with weekly follow up conducted by a physiotherapist remotely. This study provided a novel way of delivering an exercise program for patients presenting with chronic shoulder pain and produced significant improvement in pain and function, with SPADI scores significantly improved ($p < 0.001$) in six weeks.[80] The pilot study illustrates how digital platforms can enhance accessibility and adherence while maintaining clinical effectiveness.

While not home-based, the RCT conducted by Lee et al examined the effect of a 12-week resistance training program for adults aged 60 years and older who had complained of shoulder joint muscle-related pain.[81] This supervised group-based exercise program was conducted three times per week for 12 weeks. Participants in the intervention group demonstrated a significant reduction in shoulder pain ($p < 0.001$), improved shoulder joint ROM ($p < 0.001$) and increased muscle mass around the shoulder ($p < 0.001$).[81] This is one of the few studies to focus specifically on older adults with pre-existing shoulder pain, indicating the effectiveness of exercise for older adults. Collectively, these trials and reviews demonstrate that home-based exercise, whether delivered individually or enhanced via digital platforms, can produce clinically meaningful improvements in pain and function comparable to supervised or clinic-based programs.

2.6.3. Adherence to home-based exercise programs for reducing shoulder dysfunction

Predictors of adherence to home-based physical therapies in treating musculoskeletal impairment or loss of physical function were reviewed by Essery et al.[82] The systematic review of 30 studies ($n = 3321$, mean age range 22-81 years) revealed that stronger patient self-efficacy, self-motivation, social support, intentions, and past adherence to physical therapies were predictors of higher adherence to home-based physical therapy.[82] Identifying and understanding these predictors enables researchers and clinicians to better design and implement interventions that enhance facilitators and reduce barriers to adherence.

Although evidence specifically addressing home-based exercise for preventing shoulder dysfunction in older adults remains limited, home-based exercise programs targeting shoulder

dysfunction offer clear, practical advantages for older adults, including accessibility, convenience and cost-effectiveness.[83-85] While some barriers to adherence exist for home-based exercise programs, they can be addressed through behavioural strategies and ongoing support.[86]

2.6.4. Evidence gaps regarding home-based exercise for reducing shoulder dysfunction

Most evidence provided for home-based exercise programs consists of treatment for adults with pre-existing shoulder pain and/or dysfunction.[78-80] It is not clear whether home-based exercise programs can prevent future shoulder dysfunction in people with no shoulder symptoms. The research to date has also mostly focused on adults rather than older adults,[78-80] and whether this evidence can be extrapolated to an older population is unknown. Therefore, Chapter Five of this thesis investigates the effectiveness of an upper limb exercise program for improving strength, mobility and function in older adults who were not recruited with known shoulder dysfunction.

2.7. Evidence for home-based exercise for preventing falls in people with COPD

As previously introduced in Chapter One, older adults with COPD demonstrate a higher risk of falls compared to their healthier peers, due to poorer balance, reduced muscle strength and exercise capacity.[87-90] Falls risk factors established in COPD literature include increased age, female gender, fall history, polypharmacy, increased number of comorbidities, heart disease, use of supplemental oxygen, impairment in postural balance tests and smoking history.[91]

Impaired balance in people with COPD has been associated with decreased physical activity,[92] suggesting that improving physical activity and therefore balance could reduce falls. Older people with COPD also face more barriers to physical activity than their healthier peers, including limited exercise capacity.[93] COPD guidelines recommend regular cardiovascular exercise, mainly in the form of walking, but have been updated recently to include muscle strengthening exercises twice a week, as well as noting balance exercises would be beneficial.[94] Considering the challenges faced by older people with COPD, home-based exercise could be a potential strategy to incorporate physical activity into daily routines.[3,95] The evidence for home-based exercise programs to reduce falls risk among older adults with COPD will now be reviewed.

2.7.1. Systematic reviews of home-based exercise to prevent falls among adults with COPD

Multiple systematic reviews have examined fall risk and balance impairment in people with COPD.[90,91,96-98] These reviews have included home-based and group-based along with inpatient and outpatient interventions but are not entirely focused on home-based exercise. Delbressine et al[90] conducted a systematic review of exercise interventions on fall risk and balance in patients with COPD (15 studies, *n* = 842, mean age range 58-73 years). Exercise interventions had a positive effect on balance in patients with COPD, with all studies reporting improved balance after the interventions, often surpassing the minimal clinically important difference. The exercise interventions had a wide duration ranging from 3 to 28 weeks. Many different outcome measures were used to evaluate balance and fall risk was not reported in any of the studies. Pulmonary rehabilitation combined with balance training had the most beneficial effect on balance.[90] The authors concluded that the impact on fall risk and

on longer term outcomes is still uncertain. The authors also recommended further research using a consistent balance measure and focusing on long-term effects and risk of falls.[90]

The importance of addressing fall risk in COPD is underscored by Oliveira's review (23 studies, *n* = 46540, mean age range 62-76 years) on falls prevalence and risk factors in people with COPD.[91] Oliveira et al found that older people with stable COPD fall more often than the general older adult population. Furthermore, falls frequency during acute exacerbations of COPD may be higher than in stable COPD, however the evidence is limited. One study reported a higher falls incidence rate at three, six and twelve months post hospital discharge following acute exacerbations of COPD compared with those with stable COPD.[99] Therefore, given that acute exacerbations of COPD may increase fall risk, fall mitigation strategies should be put in place following hospital discharge, however more research is needed in this area. As Oliveira noted, the absence of prospective fall outcome reporting makes it difficult to determine the effect of an intervention, including home-based exercise, on actual fall incidence.[99]

Loughran et al further reinforced this gap,[96] with their systematic review and meta-analysis of 34 studies (*n* = 1712) on exercise-based interventions targeting balance and falls in people with COPD.[96] Loughran et al observed that the evidence supporting exercise-based interventions for achieving clinically meaningful balance improvements was weak, with statistically significant but clinically modest improvements in balance outcomes. Targeted balance training alongside pulmonary rehabilitation showed the greatest benefit compared with general exercise alone.[96] There were uncertain effects on fall prevention with very limited and inconclusive evidence, with no studies measuring falls as a primary outcome.

Overall, exercise programs, particularly those that include targeted balance training, seem to improve balance performance and confidence; however, it is still unclear whether these gains translate into a reduced risk of falls. This highlights the need for research that evaluates falls as a long-term outcome.

Similarly, Chuatrakoon's systematic review of 19 studies (n = 1047) on balance impairment and effectiveness of exercise intervention in people with COPD confirmed that people with COPD have impaired balance. Findings demonstrated significantly lower Berg Balance Scale (BBS) scores (32-51 out of 56 compared with 51-56 out of 56 points on the BBS). The authors concluded that balance training may be effective in improving balance performance,[97] however the effectiveness of exercise interventions on balance performance in people with COPD is unknown.[97]

Multiple systematic reviews have reported improvements in balance among older people with COPD from targeted balance training.[90,91,96-98] However, these studies did not measure fall-related outcomes. The authors concluded that further research is needed using prospective recording of falls,[91] standardised measures of balance in COPD to adequately assess the effects of different interventions,[90] and the inclusion of behaviour change techniques to enhance adherence.[96]

Despite these limitations, the wider literature on home-based pulmonary rehabilitation (PR) provides useful context. Pinto et al conducted a systematic review (five studies, n = 640) on maintaining effects of pulmonary rehabilitation at home in COPD including components of home-based pulmonary rehabilitation programs and maintenance strategies.[100] They

recommended that maintenance programs should be implemented following an outpatient pulmonary rehabilitation program to ensure the continued benefits of the initial program. These unsupervised home-based maintenance programs should include an educational component, aerobic exercise component and strength training component. The authors also acknowledged that it is important to include more functional exercises targeted to the participant's goals and needs.[100] Although falls were not examined, these findings demonstrate that structured home-based exercise is feasible and may be suited to individuals who may have difficulty accessing centre-based programs.

2.7.2. RCTs of home-based exercise to prevent falls among older adults with COPD

To date, three studies have investigated home-based fall prevention exercise in older people with COPD, including two randomised controlled trials[101,102] and one feasibility study.[103]A study by Chuatrakoon evaluated the effectiveness of a home-based balance and pulmonary rehabilitation program in people with COPD on balance, fall risk and respiratory symptoms.[102] The authors reported reduced risk of falls with significantly greater improvements in the primary outcomes of fall risk measured by the Physiological Profile Assessment (PPA) ($p < 0.01$) and functional balance measured by the Timed Up and GO (TUG) ($p < 0.01$). Improved balance confidence and reduced dyspnoea ($p < 0.05$) was reported at 8 weeks and 3 months. However, there was no difference in the 6 minute walk distance at either follow-up time points.[102]

A RCT by Hao et al ($n = 245$, mean age 72 years) incorporated balance training into pulmonary rehabilitation and provided an additional home-based balance exercise program for an additional 10 months beyond the two-month pulmonary rehabilitation program.[101] The

primary outcome was the incidence of falls at 12 months, which was exactly the same in both the intervention and control groups (128 per 100 person-years and 128 per 100 person-years). There was a significant difference in favour of the intervention group in balance (measured by the Berg Balance Scale, $p = 0.038$) and leg strength (measured by the 30-second sit to stand test, $p = 0.034$) immediately following the completion of the pulmonary rehabilitation program but not at the 12-month follow up.[101] The authors did note that there were issues with adherence to the program over the 12-month period, which may have been impacted by trial overlapping with the COVID-19 pandemic period.[101] Strategies, including behaviour change techniques and digital and/or virtual support, should be considered to promote adherence.

One of the few studies which explicitly considered exercise for preventing falls among older adults with COPD was a feasibility study of a six-month home-based fall prevention exercise program in older adults with COPD.[103] The primary aim of the study was to determine the feasibility of a home-based fall prevention exercise program, as a new way to address the prevention of falls in patients with COPD who were not enrolled in pulmonary rehabilitation.[103] This is important given the low rates of uptake of pulmonary rehabilitation[104] and limited access to pulmonary rehabilitation programs for some people living in regional areas.[105,106] This feasibility study did not have a control group, however there were significant improvements in balance (Berg Balance Scale) at six months (MD 2.5; 95% CI -4.6 to -0.3) and non-significant improvements in fear of falling, functional strength and physical function.[103] The authors also noted that alternate modes of delivery (such as virtual) should be considered in future home-based exercise programs.[103]

Research has been conducted into home-based pulmonary rehabilitation programs for people with COPD, which appear to be acceptable and produce similar outcomes to conventional centre-based pulmonary rehabilitation.[95,107] Given the unique challenges faced by older people with COPD, such as shortness of breath, use of supplemental oxygen, reduced functional capacity, difficulty walking long distances and complex comorbidities,[103,108,109] it is crucial to provide avenues for physical activity that can be incorporated into their lifestyle to reduce their risk of falling and improve exercise capacity and quality of life. Innovative evidence-based approaches are required to support people with COPD by addressing some of the barriers in accessing programs.[109]

2.7.3. Adherence to home-based exercise to prevent falls among older adults with COPD

A key factor influencing adherence to exercise among older adults with COPD is physical symptoms. It is worth noting that one of the main reasons for participants declining to participate in the previous feasibility study was not feeling well enough to exercise which is commonly reported in people with COPD.[103] A subsequent qualitative exploration of this feasibility study was undertaken to understand the experiences of participants with COPD who participated in a home-based exercise program.[108] Two major themes were identified: program personalisation and self-motivation/support.

The authors identified that program personalisation based on individual characteristics, lifestyles and preferences was an important factor influencing participation. Participants reported having varying health limitations such as frequent exacerbations, arthritis limiting physical functioning, limited mobility and pain, and that these health limitations made it difficult to complete the exercises. Differing physical fitness levels of participants were

reported, resulting in the exercises being either too easy or too challenging.[108] These findings reinforce the importance of tailoring of exercise for individual participants. Different mediums of delivery such as paper vs DVD-based implementation were discussed, with more participants preferring paper-based program materials; however personal preferences should be considered when delivering a home-based exercise program.

The second major theme identified influencing participation in the program was self-motivation and support, where participants described the role of internal drive and encouragement from family, friends and healthcare providers in sustaining engagement with the program.[108] Many noted that having support helped them stay motivated over the six months, underscoring that adherence to home-based exercise is influenced not only by the exercises themselves but also by the broader support surrounding participants. This is more important in a home-based exercise program as people are completing the exercises individually and are not receiving peer support as often experienced in group-based exercise programs. The authors recognised that people who do not have strong social support systems may require additional support and follow-up from healthcare providers.[108]

As a result of their qualitative findings, Chauvin et al developed a list of recommendations for future home-based fall prevention exercise programs for people with COPD.[108] These recommendations included:

- Modifying or progressing exercises based on the individual's physical fitness levels
- Taking into account individuals' personal commitments and responsibilities

- Determining location preferences of each individual (e.g., at home or in the community)
- Providing multiple implementation mediums (e.g., paper-based, DVD, online)
- Incorporating social support from healthcare providers when self-motivation or social support from family and friends is not available.

Novel adaptations of home-based fall prevention exercise to allow participants choice in how the exercise intervention is delivered appears to be important.[108] Traditional options include paper or DVD-based resources, however online or virtual delivery could also be an option for older people with COPD.[108] In the study presented in Chapter Six, the home-based exercise program for people with COPD is supported with virtual technology, after initial instruction is provided in small groups, and with paper-based program materials.

2.7.4. Evidence gaps regarding home-based exercise to prevent falls among adults with COPD

From this research it was demonstrated that there is still much to learn regarding the prevention of falls in older people with COPD. No studies have explored the effectiveness of the OEP in people with COPD. This gap in the evidence regarding the implementation of home-based exercise programs to prevent falls in people with COPD is addressed in Chapter Six.

2.8. Methodological considerations

2.8.1. Rationale and design

A pragmatic research paradigm underpins this thesis, reflecting a focus on generating knowledge that is directly applicable to real-world practice.[110] From an ontological perspective, this approach recognises that health outcomes such as falls and functional decline arise from complex, multifactorial interactions rather than a single objective reality.[111] Epistemologically, it prioritises the use of methods that best address the research question, combining objective measurement with behavioural understanding.[112] This aligns with applied public health research and supports the integration of multiple complementary methodologies.[112]

The selection of methodologies within this thesis was aligned with the overarching aim of investigating new implementation approaches for home-based exercise programs for older adults. A summary review of the literature was undertaken to synthesise a broad evidence base relating to falls prevention, upper limb dysfunction and exercise interventions for older adults. Although a more rigorous review of systematic reviews was considered, it would have limited the ability to include newer and more context-specific evidence that was important for shaping the intervention.[111]

A pragmatic randomised controlled trial was selected to evaluate effectiveness under real-world conditions.[113] A pilot study to assess feasibility and acceptability was used to determine the suitability of this home-based exercise program for a group of older adults with COPD, who have a much greater risk of falls compared to healthier peers.[87,89,90]

The pragmatic RCT design was selected as it represents the most appropriate method for determining intervention effectiveness while maintaining external validity. Pragmatic trials are designed to reflect routine practice, thereby enhancing generalisability.[114] Random allocation to intervention minimised selection bias. While participant blinding was not feasible due to the nature of the intervention, this limitation was mitigated through blinded outcome assessment and the use of objective measures where possible. An intention-to-treat analysis approach minimised bias from missing data, preserved the benefits of randomisation and provided a 'real world' estimate of effectiveness.[115]

The upper limb exercise program was included to provide a relevant comparison condition and to allow evaluation of its specific effects on upper limb function. Its inclusion also served as an active control, enabling the lower limb program to be assessed against another structured, purposeful intervention rather than a passive or non-exercise control. This design ensures that any observed differences between programs can be attributed to the focus of the intervention rather than to general engagement in exercise. In this way, the study effectively incorporated two parallel trials within a single framework.

The 12-month follow-up period was selected to ensure adequate exposure to the intervention and to capture outcomes such as falls and upper limb dysfunction, which require longer observation periods for accurate assessment as falls can occur intermittently.[116] The inclusion of group-based workshops to teach a home-based exercise program reflects a pragmatic and scalable delivery model, addressing known barriers to exercise participation among older adults, including accessibility, cost, and preference for home-based activity.

2.8.2. Primary outcome measures

The first primary outcome, rate of falls, was recorded using monthly calendars over a 12-month period. This was selected due to its direct clinical and public health relevance. Falls are a leading cause of morbidity in older adults, and fall rate is considered the most sensitive and recommended outcome in falls prevention trials.[116,117] Prospective monthly calendars are widely regarded as the gold standard for falls data collection, as they minimise recall bias and enable detailed follow-up of fall events.[116]

The second primary outcome, upper limb function, was assessed using the Disability of the Arm, Shoulder and Hand (DASH) questionnaire.[118,119] The DASH is a validated self-report measure capturing symptoms and functional limitations across the upper limb. The DASH was selected due to its comprehensive scope and relevance to daily activities, making it appropriate for detecting clinically meaningful changes in function.[120] In contrast, more region-specific measures such as the Shoulder Pain and Disability Index focus primarily on shoulder-related symptoms and may not adequately capture broader upper limb disability.[120] The DASH was therefore considered more aligned with the study aim of assessing functional outcomes at the level of the whole limb.

2.8.3. Secondary outcome measures

A comprehensive set of secondary outcome measures was selected to capture the multifactorial nature of fall risk, upper limb dysfunction and physical function. The Short Physical Performance Battery (SPPB) was chosen as a measure of lower limb function due to its strong validity, reliability, and predictive ability for adverse outcomes such as disability and institutionalisation in older populations.[121] The SPPB assesses balance, gait speed, and

lower limb strength, providing a composite measure closely aligned with mechanisms underlying falls risk. Alternative measures, such as the Berg Balance Scale and the Timed Up and Go, were considered. However, the Berg Balance Scale may demonstrate ceiling effects in higher-functioning individuals,[122] and the Timed Up and Go provides a more limited assessment of physical performance.[123] The SPPB was therefore considered more sensitive to change and better suited to a community-dwelling population.

The alternate step test was included to assess dynamic balance and coordination, which are critical but often underrepresented components of falls risk. This test captures rapid weight shifting and stepping ability, reflecting functional tasks encountered in daily life.[124] The alternate step test was selected due to its feasibility, minimal equipment requirements, and suitability for large-scale community implementation.

Measuring fear of falling using the Falls Efficacy Scale-International (FES-I) is strongly supported by evidence and allows assessment of concern about falling across a range of daily activities.[125,126] A key strength of the FES-I is its ability to capture the functional consequences of fear of falling, including activity restriction and avoidance behaviours. Fear of falling has been shown to be independently associated with reduced physical activity, poorer quality of life, and increased risk of future falls, even among those without a prior fall history.[127]

Physical activity was assessed both by self-report with the Incidental and Planned Exercise Questionnaire (IPEQ)[128] and objectively with accelerometers. Due to the limited agreement between methods, the distinct aspects of physical activity captured by each method and

differences in the dimensions assessed, it has been recommended that studies incorporate both self-report questionnaires and accelerometry to provide a more comprehensive evaluation of physical activity.[129]

The SF-12v2 Health Survey was used to assess health-related quality of life, as it provides a valid and reliable measure of both physical and mental health domains while minimising participant burden.[130] It has demonstrated strong agreement with the longer SF-36 Health Survey and is sensitive to differences between groups and changes over time, making it appropriate for intervention studies.[131,132] From a practical perspective, it is relatively quick to administer and easy to score, making it suitable for older adult populations and studies incorporating multiple outcome measures.[130,131]

The inclusion of both objective and self-reported measures reflects a deliberate methodological choice to capture complementary dimensions of function and behaviour. Objective measures provide precise quantification of physical capacity, while self-reported measures capture perceived ability, participation, and psychosocial factors, all of which are important determinants of health outcomes in older adults.

Quadriceps strength was measured using an electronic weight scale during seated knee extension and is a valid, simple, and reliable method for assessing lower limb strength in older adults.[133] This approach has been widely used in fall prevention research, as it provides an objective estimate of isometric force while remaining feasible in community settings. This method is particularly advantageous due to its portability and ease of use, making it suitable for a large-scale study. Participants are instructed to perform a maximal isometric contraction

against a fixed strap, with the peak force (the best of three trials) recorded. Evidence suggests that this protocol is sensitive to differences in strength and capable of detecting changes over time, supporting its use as an outcome measure in exercise interventions targeting lower limb function.[133] While isokinetic dynamometry is considered the gold standard for muscle strength assessment, simpler field-based methods such as weight scale protocols are less precise but provide a valid, reliable, and feasible alternative for use in older adult and community-based research. These methods are particularly appropriate for assessing lower limb strength due to their accessibility, safety, and demonstrated associations with functional performance and falls risk.[133,134]

Shoulder internal and external rotation strength was measured using hand-held dynamometry, which is a valid and reliable method for assessing upper limb strength.[134] Standardised testing protocols, typically involving 90° shoulder abduction and 90° elbow flexion, demonstrate good-to-excellent reliability, particularly when a "make test" approach and consistent stabilisation are used.[135] Hand-held dynamometers are portable and easy to use, making them a practical and responsive tool for detecting changes in strength following exercise interventions, and supporting their widespread use in both clinical and research settings.[134]

Shoulder internal and external rotation range of motion was assessed using a digital inclinometer, a method shown to be valid and reliable for measuring joint mobility in both clinical and research settings. Studies have demonstrated good-to-excellent intra- and inter-rater reliability for shoulder rotation measurements when standardised positioning (e.g. 90° shoulder abduction and 90° elbow flexion) and stabilisation are applied.[136,137] Digital inclinometers may offer advantages over traditional goniometry, including improved ease of

alignment and reduced measurement error, while maintaining comparable or superior reliability.[136]

Program acceptability was assessed using questionnaires administered at three, six, and twelve months. These questionnaires asked participants about their confidence in completing the exercises at home, their intention to continue the exercises and whether they would recommend the program to others. Participants were also asked which features of the program they found most helpful and whether they experienced any barriers to completing the exercises regularly. In a large randomised controlled trial, the use of structured survey questions to assess acceptability is both pragmatic and methodologically appropriate. Although qualitative interviews can provide richer, in-depth insights, they are often not feasible at scale in trials of this size.[112] The use of questionnaires enabled efficient data collection across the full sample and allowed quantification and comparison of acceptability between groups. This approach is consistent with guidance from the United Kingdom Medical Research Council, which notes that acceptability can be assessed quantitatively through participant-reported measures, such as questionnaires, as part of a process evaluation conducted alongside trial outcomes.[112]

Alternative measurement approaches, including clinically based strength testing, were considered but deemed inappropriate due to their limited feasibility, higher cost, and reduced scalability within a community-based trial. The selected measures represented a balance between methodological rigour and practical applicability.

Overall, the methodological approach adopted in this thesis reflects a justified strategy that integrates a pragmatic approach with robust and appropriate research methods. The combination of a literature summary, pragmatic RCT and pilot study, validated and clinically relevant outcome measures, and consideration of feasibility and scalability ensures that the findings are both scientifically rigorous and directly translatable to real-world practice.

2.9. Conclusion

Chapter Two examined the evidence supporting home-based exercise programs for preventing falls and upper limb dysfunction in older adults, as well as preventing falls among older adults with COPD. Overall, the literature indicates that home-based exercise programs are effective, accessible and cost-effective, particularly for older adults facing barriers in attending group-based exercise programs. The Otago Exercise Program is a well-established intervention shown to significantly reduce falls in older adults. Systematic reviews further demonstrate that home-based exercise interventions improve balance, strength and physical function, although improvements in upper limb strength are limited when programs do not include targeted upper body exercises. Adherence remains a challenge, influenced by program design and personal factors.

Chapter Two also reviewed the evidence on home-based exercise for managing and preventing shoulder dysfunction. Existing studies suggest that home-based exercise programs can be as effective as supervised physiotherapy in reducing pain and improving function. However, the evidence is limited, with most studies focused on adults rather than older adults and treatment rather than prevention. Additionally, while home-based pulmonary rehabilitation has been shown to be effective for people with COPD, there is little research on

home-based fall prevention programs targeted to this high-risk population. Chapter Two also detailed the methodological considerations underpinning the thesis, providing the foundation for the selected approach.

The subsequent chapters of this thesis address the gaps identified in the literature. Chapter Three outlines the objectives and methodology of the prospectively registered randomised controlled trial testing two home-based exercise programs. Chapter Four presents the results of a home-based exercise program to prevent falls in community-dwelling older adults. Chapter Five reports on the outcomes of a home-based exercise program aimed at preventing upper limb dysfunction in community-dwelling older adults. Chapter Six describes the findings from a pilot study of a novel home-based exercise program for older adults with COPD.

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Chapter 3: Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at Home randomised controlled trial.

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Bates A, Furber S, Tiedemann A, Ginn K, van den Dolder P, Howard K, Bauman A, Chittenden C, Franco L, Kershaw M, Sherrington C. Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at home randomised, controlled trial. J Physiother. 2018;64(2):121. https://doi.org/10.1016/j.jphys.2017.10.001

Authorship contribution statement

As primary supervisor and co-author of the paper “Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at home randomised, controlled trial”, I confirm that Amanda Macaulay (Bates) is the lead corresponding author and has made the primary contribution to this study in each of the following areas in collaboration with co-authors Furber S, Tiedemann A, Ginn K, van den Dolder P, Howard K, Bauman A, Chittenden C, Franco L, Kershaw M, Sherrington C:

- Conception and design of the research
- Writing of the manuscript and critical appraisal of the content

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

Preamble to Chapter Three

This chapter describes in detail the study protocol for the pragmatic randomised controlled trial reported in Chapters Four and Five. The chapter details the methodology in advance of conducting the trial, in order to reduce bias and enhance rigor. The purpose of the trial was to test a pragmatic home-based exercise intervention to prevent falls and upper limb dysfunction in adults aged 65 years and over living in the community.

The BEST at Home intervention was designed in reference to the Social Cognitive Theory (SCT), which explains behaviour as the interaction between personal factors, behaviour, and the environment.(Bandura 2004) Several elements of the BEST at Home program reflect key SCT constructs. The provision of exercise instruction, written materials, and equipment supports behavioural capability by giving participants the knowledge and skills needed to perform the exercises.(Bandura 2004) Group-based sessions led by physiotherapists also allow for observational learning, where participants can learn by watching others. In addition, tailoring exercises to individual ability may help improve self-efficacy, or confidence in the ability to exercise, which is a key predictor of physical activity in older adults (McAuley 2011, White 2012). The program also includes features that support behaviour change, such as education about falls prevention and the use of exercise calendars. These may influence outcome expectations (beliefs about the benefits of exercise) and introduce self-monitoring, which is an important part of behaviour change (White 2012).

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Appraisal

Trial Protocol: Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at Home randomised, controlled trial

Amanda Bates [a], Susan Furber [a,b], Anne Tiedemann [c], Karen Ginn [d], Paul van den Dolder [a], Kirsten Howard [c], Adrian Bauman [c], Cathy Chittenden [a], Lisa Franco [a], Michelle Kershaw [a], Catherine Sherrington [c]

[a] *Ambulatory and Primary Health Care, Illawarra Shoalhaven Local Health District, Wollongong;* [b] *School of Public Health and Community Medicine, University of New South Wales, Sydney;* [c] *School of Public Health, The University of Sydney, Sydney;* [d] *School of Medical Sciences, The University of Sydney, Sydney Australia*

Abstract

Introduction: Falling when older is a major public health issue. There is compelling evidence to show that specific exercise programs can reduce the risk and rate of falls in community-dwelling older people. Another major health issue for older people living in the community is upper limb dysfunction, including shoulder pain. Home-based exercise programs appeal to some older people, due to their convenience. **Research questions**: This trial aims to determine the effectiveness and cost-effectiveness of a home-based lower limb exercise program compared with a home-based upper limb exercise program to prevent falls and upper limb dysfunction among community-dwelling people aged 65+ years. **Design**: Randomised, controlled trial. **Participants and setting**: A total of 576 community-dwelling people will be recruited from the Illawarra and Shoalhaven regions of New South Wales, Australia. **Intervention**: Participants will be randomised to either a home-based lower limb exercise intervention or a home-based upper limb exercise intervention. The lower limb program is designed to improve balance and strength in the lower limbs. The upper limb program is designed to improve upper limb strength and mobility. Participants will attend three group-based instruction sessions to learn and progress the exercises, and will be instructed to perform the exercises three times per week at home for 12 months. **Outcome measures**: The two primary outcomes will be fall rates, recorded with monthly calendars for a 12-month period, and upper limb dysfunction, measured with the Disability of the Arm, Shoulder and Hand questionnaire. Secondary outcomes will include: lower limb strength and balance; shoulder strength and mobility; physical activity; quality of life; attitudes to exercise; proportion of fallers; fear of falling; and health and community service use. The cost-effectiveness of both exercise programs from a health and community service provider perspective will be evaluated. **Analysis**: Negative binomial regression models will be used to estimate the between-group difference in fall rates. Modified Poisson regression models will be used to compare groups on dichotomous outcome measures. Linear regression models will be used to assess the effect of group allocation on the continuously scored measures, after adjusting for baseline scores. Two economic evaluations will be conducted: the first will assess cost-effectiveness of the lower limb program compared with the upper limb program; and the second will assess cost-effectiveness of the upper limb program compared with the lower limb program. **Discussion**: If effective, the trial will provide a model for both upper limb and lower limb exercise programs that can be performed at home and implemented at scale to community-dwelling older adults.

Trial registration: Australian and New Zealand Clinical Trials Registry. **Registration number**: ACTRN12615000865516. **Was this trial prospectively registered?** Yes. **Date of trial registration**: 19 August 2015. **Funded by**: This trial is funded by the National Health and Medical Research Council of Australia. The funders had no role in the trial design and will not have any role during its execution, analyses, interpretation of the data, or decision to submit results. **Funder approval number**: APP1077034. **Anticipated completion date**: 31 June 2018. **Correspondence**: Anne Tiedemann, The University of Sydney, Musculoskeletal Health Sydney, School of Public Health, PO Box 179, Missenden Road, New South Wales 2050, Australia. **Email**: anne.tiedemann@sydney.edu.au

Provenance: Not invited. Peer reviewed.

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Journal of Physiotherapy

Study title: Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at Home randomised controlled trial

Author names: Amanda Bates[1], Susan Furber[1, 2], Anne Tiedemann[3], Karen Ginn[4], Paul van den Dolder[1], Kirsten Howard[3], Adrian Bauman[3], Cathy Chittenden[1], Lisa Franco[1], Michelle Kershaw[1], Cathie Sherrington[3]

Institutional affiliations:

[1] Ambulatory and Primary Health Care, Illawarra Shoalhaven Local Health District, NSW, Australia

[2] School of Public Health and Community Medicine, University of New South Wales, Sydney, Australia

[3] Musculoskeletal Health Sydney, School of Public Health, The University of Sydney, Sydney, Australia

[4]School of Medical Sciences, The University of Sydney, Sydney, Australia

Abstract

Introduction: Falling in older age is a major public health issue. There is compelling evidence that specific exercise programs can reduce the risk and rate of falls in community-dwelling older people. Another major health issue for older people living in the community is upper limb dysfunction, including shoulder pain. Home-based exercise programs appeal to some older people due to their convenience. **Research questions:** This trial aims to determine the effectiveness and cost-effectiveness of a home-based lower limb exercise

program compared with a home-based upper limb exercise program to prevent falls and upper limb dysfunction among community-dwelling people aged 65+ years. **Design:** Randomised controlled trial. **Participants and setting:** 576 community-dwelling people will be recruited from the Illawarra and Shoalhaven regions of New South Wales, Australia. **Intervention:** Participants will be randomised to either a home-based lower limb exercise intervention or a home-based upper limb exercise intervention. The lower limb program is designed to improve balance and strength in the lower limbs. The upper limb program is designed to improve upper limb strength and mobility. Participants will attend three group-based instruction sessions to learn and progress the exercises and will be instructed to perform the exercises three times per week at home for 12 months. **Outcome measures:** The two primary outcomes will be fall rates, recorded with monthly calendars for a 12-month period; and upper limb dysfunction, measured with the Disability of the Arm, Shoulder and Hand questionnaire. Secondary outcomes include lower limb strength and balance, shoulder strength and mobility, physical activity, quality of life, attitudes to exercise, proportion of fallers, fear of falling, health and community service use. The cost-effectiveness of both exercise programs from a health and community service provider perspective will be evaluated. **Analysis:** Negative binomial regression models will be used to estimate the between-group difference in fall rates. Modified Poisson regression models will be used to compare groups on dichotomous outcome measures. Linear regression models will be used to assess the effect of group allocation on the continuously-scored measures, after adjusting for baseline scores. Two economic evaluations will be conducted. The first will assess the cost-effectiveness of the lower limb program compared to the upper limb program, and the second will assess the cost effectiveness of the upper limb program compared to the lower limb program.

Discussion: If effective, the trial will provide a model for both upper limb and lower limb exercise programs which can be performed at home and implemented at scale to community-dwelling older adults.

Trial registration: Australian and New Zealand Clinical Trials Registry. **Registration number**: ACTRN12615000865516. **Was this trial prospectively registered?** Yes
Date of trial registration: 19 August 2015. **Funded by**: This trial is funded by the National Health and Medical Research Council of Australia. The funders had no role in the trial design and will not have any role during its execution, analyses, interpretation of the data, or decision to submit results. **Funder approval number**: APP1077034. **Anticipated completion date:** 31 June 2018. **Correspondence:** Anne Tiedemann, The University of Sydney, Musculoskeletal Health Sydney, School of Public Health, PO Box 179, Missenden Road, New South Wales 2050, Australia. **Email:** anne.tiedemann@sydney.edu.au

Provenance: Not invited. Peer reviewed

Study title

Home-based exercise programs to prevent falls and upper limb dysfunction among community-dwelling older people: study protocol for the BEST (Balance Exercise Strength Training) at Home randomised controlled trial

Human research ethics approval committee: The protocol has been approved by the Human Research Ethics Committee from the University of Wollongong and Illawarra Shoalhaven Local Health District, Australia.

Human research ethics approval number: HE14/279 and HREC/14/WGONG/50

Introduction

Falls are a major and increasing public health issue. In New South Wales (NSW), Australia, more than 25% of people over the age of 65 years fall at least once each year.[1] In 2006/07 in NSW the total cost of health care associated with fall injuries in older people was estimated at $558.5 million.[2] Falls experienced by people living in the community accounted for 85% of these costs.[2] The impact of falls is predicted to increase substantially in the near future due to the increased proportion of older people in the population. The proportion of Australians aged 65 years or over is predicted to increase from 13% (3 million people) in 2010 to 25% (10.5 million people) by 2050.[3]

There is compelling evidence that exercise programs can reduce the risk and rate of falls in community-dwelling older people.[4,5] Fall prevention effects are maximised if exercise programs include a high challenge to balance and at least three hours per week of exercise.[5] However, according to a survey of 5681 older people in NSW, Australia, only one in eight respondents (12%) participated in strength training and 6% participated in balance training in

the previous week; and only 2% participated in both strength and balance training at the recommended level.[6] This highlights a clear need for strategies to promote uptake and ongoing participation in effective fall prevention programs.

Exercise programs for older people can be effective in preventing falls if delivered in either a group or home-based format,[4,5] but home-based programs are more appealing to many older people due to their greater convenience.[7,8] Home-based strength and balance training has also been shown to be safe and effective in improving balance and strength.[9-11]

The Otago Exercise Programme is an effective home-based fall prevention program involving strength and balance exercises.[9] When provided by physiotherapists or trained community nurses via five home visits over six months,[12] the Otago Exercise Programme demonstrated a 35% reduction in the number of falls and injuries from falls in older community-dwelling adults.[9,13,14] Bates and colleagues piloted a new method of delivery for the Otago Exercise Programme that used group sessions to deliver the exercise instruction instead of home visits.[15] This delivery method was effective in increasing strength and balance and had high acceptance by community-dwelling older people, yet the impact on falls has not been assessed.

Upper limb dysfunction, including shoulder pain is another major health issue for older people living in the community.[16] Shoulder pain is the third most common musculoskeletal disorder in adults.[17] The prevalence of shoulder pain increases with age,[18,19] with estimates of the point prevalence of shoulder pain in adults aged 70+ years of 13-26%.[20] Home-based exercise is a common strategy for treating shoulder disorders[21] with moderate evidence from systematic reviews supporting the efficacy of this approach.[22,23] However, to our knowledge,

there are no studies that have evaluated the efficacy of upper limb exercise programs for the prevention of upper limb dysfunction in older people living in the community.

The primary aim of this trial is to determine the comparative effectiveness of a home-based lower limb exercise program and a home-based upper limb exercise program to prevent falls and upper limb dysfunction among community-dwelling people aged 65 years and over. The secondary aims are to establish the impact of each exercise program on the proportion of fallers, fear of falling, physical activity, lower limb strength, balance, shoulder strength, shoulder mobility, attitudes to exercise, quality of life, and health and community service use. We also aim to evaluate the cost-effectiveness of both the upper and lower limb exercise programs from a health and community service provider perspective.

Design

A randomised controlled trial will be conducted. The design of the trial is shown in Figure 1. Approval to conduct this trial has been granted by the Human Research Ethics Committee from the University of Wollongong and Illawarra Shoalhaven Local Health District (HE14/279 and HREC/14/WGONG/50). The study is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12615000865516). This trial has been designed according to the CONsolidated Standards Of Reporting Trials (CONSORT) statement,[24] and is reported according to the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statement,[25] and with reference to the Template for Intervention Description and Replication (TIDieR) checklist.[26]

Methods

Participants

Eligible participants will be community-dwelling people aged 65 years or over. Potential participants will be excluded if they have any of the following: cognitive impairment (assessed by a Memory Impairment Screen score of less than 5);[27] inability to walk 10 metres despite assistance from a walking aid; insufficient English language skills to read and understand program materials; a progressive neurological disease (e.g. Parkinson's disease, multiple sclerosis); fracture or joint replacement within the last six months; a medical condition precluding exercise (e.g. unstable cardiac disease, uncontrolled hypertension, uncontrolled metabolic diseases); unable to obtain medical clearance; currently participating in an exercise program two or more times per week that is similar to either the upper limb or lower limb exercise program.

Details of the exercise programs

Lower limb exercise program

Participants allocated to the lower limb exercise group will receive a home-based exercise program to improve balance and strength in the lower body. This program is based on the Otago Exercise Programme[9,28] and includes the following exercises: knee extension and knee flexion, hip abduction, calf raises, toes raises, sit to stand, semi squats from a standing position, tandem stand, tandem walk, sideways walking, backwards walking, heel walking, toe walking, one leg stand, and walking and turning around. Participants will be instructed to perform 10-20 repetitions of the exercises, three times per week at home, as prescribed in the Otago Exercise Programme.[28] Participants will be provided with an ankle cuff weight (0.5kg – 5kg), and the weight will be determined by the physiotherapist at the first session, depending on individual ability. A home exercise program manual containing diagrams and

descriptions of the exercises and a copy of '*Staying Active and On Your Feet'*, a booklet produced by NSW Health about preventing falls[29] will also be provided to all participants. Participants will be shown progressions for each of the exercises and encouraged to make the balance exercises challenging.

Upper limb exercise program

The upper limb exercise group will receive a home-based exercise program designed by members of the research team to improve upper limb strength and mobility, and reduce dysfunction. Exercises will include arm raises, internal and external shoulder rotation, elbow flexion and extension, shoulder press, chest press and shoulder row. Participants will be provided with a pair of dumbbell weights (600g – 3kg), with the weight to be determined by the physiotherapist at the first session, an elastic exercise band (with options of light, medium, heavy or extra heavy resistance) and a home exercise program manual which contains diagrams and descriptions of the exercises. Participants will be instructed to perform 10 repetitions of each exercise during three exercise sessions per week at home. The upper limb exercise program will be performed with an emphasis on optimal scapular positioning and control without compensatory trunk movement.[30] The exercises should not provoke any shoulder symptoms or signs, for example pain or clicking sounds, during the execution of the exercises or within 12 hours of completing the exercises. All exercises in the upper limb program will be performed in a seated position, to reduce the likely impact on balance and fall prevention and hence to reduce the contamination effect with respect to the lower limb program.

The instruction for both lower and upper limb exercise programs will be delivered by two experienced physiotherapists in three group workshops. Exercise instruction workshops will

occur at weeks 1, 4 and 12. The program will be tailored to each participant's level of ability. At each workshop, the exercises will be reviewed, technique corrected and exercises adjusted according to the ability of each participant. It is anticipated that each workshop will include approximately 10 participants. Table 1 summarises the content of both interventions. Both upper and lower limb exercise programs were designed with reference to the social cognitive theory.[31]

Primary and secondary outcome measures and assessment points

Primary outcomes

The two primary outcomes will be: 1) fall rates, recorded with monthly calendars for a 12-month period;[32] and 2) upper limb dysfunction, measured with the Disability of the Arm, Shoulder and Hand (DASH) questionnaire.[33]

A fall will be defined as 'an unexpected event in which the participant comes to rest on the ground, floor, or lower level'.[32] Falls will be recorded using monthly calendars for a 12-month period after randomisation. Calendars will be returned in reply paid, preaddressed envelopes. Participants who do not return their calendars will be telephoned to ask about falls for that month. Participants who report a fall will also be telephoned to confirm the fall and obtain details about fall location, resulting injuries and what treatment was sought.

Upper limb dysfunction will be measured using the DASH questionnaire. The DASH measures physical disability and symptoms in people with single or multiple disorders in the upper limb.[33,34] It includes 30 items, that are rated on a 5-point scale to represent: the difficulty experienced in performing various physical activities that require upper extremity function (physical function, 21 items); symptoms of pain, activity-related pain, tingling,

weakness, and stiffness (pain symptoms, 5 items); and impact of disability and symptoms on social activities, work, sleep, and psychological well-being (emotional and social function, 4 items).[34] Scores range from zero to 100, with zero equal to no disability and 100 to the most severe disability.[35] The DASH has demonstrated good test-retest reliability (ICC 2,1 = 0.93) with sensitivity of 82% and specificity of 74%.[36]

Secondary outcomes

The secondary outcome measures will be lower limb strength and balance, shoulder strength and shoulder mobility, physical activity (Actigraph and self-reported), quality of life, attitudes to exercise, proportion of fallers, fear of falling, and health and community service use. All secondary outcomes will be measured at baseline, 3, 6 and 12 months after randomisation, except for the proportion of fallers and health and community service use (ascertained with monthly calendars), physical activity (Actigraph) (measured at baseline, 6 and 12 months), and lower limb strength and balance, shoulder strength and mobility (measured at baseline, 3 and 6 months).

Lower limb strength and balance will be assessed with the Short Physical Performance Battery (SPPB), the alternate step test and a knee extension (quadriceps) strength test. The SPPB measures balance, gait and strength of the lower limbs and includes side-by-side, semi-tandem, and tandem standing tests, sit-to-stand (5 repetitions) and a timed 4 metre walk. The SPPB is a measure of lower extremity physical performance and is practical and safe to deliver in older adults.[37-39] The alternate step test is a modified version of one of the components of the Berg Balance Scale.[40,41] The test involves placing the whole foot onto a step (18cm high) and alternating right and left feet, four times each foot. The time taken (measured in seconds) to complete the eight foot taps is recorded.[42] Quadriceps strength on

both left and right legs will be assessed with an electronic weight scale during seated knee extension.[43] The participant will be seated on a chair with hips at 90 degrees of flexion and knees just under 90 degrees of flexion so that the force is recorded at 90 degrees of flexion. The participant will be instructed to push against the strap with maximal force for two to three seconds. The best score of three attempts will be recorded for both left and right legs.

Shoulder strength will be measured by isometric shoulder internal and external rotation force in both left and right arms using a Lafayette manual muscle tester (Model 01165). The participant will be in supine with knees bent, with their shoulder at 90 degrees of abduction in the coronal plane. The elbow will be flexed to 90 degrees, forearm pronated and the shoulder fully supported in neutral horizontal positioning. The manual muscle tester will be placed proximal to the ulnar styloid process. The assessor will instruct the participant to rotate their forearm forwards (internal rotation) producing a force building to maximum contraction. The assessor will match the participant's force and record the score. Returning to the starting position, the assessor will then instruct the participant to rotate their forearm backwards (external rotation) producing a force building to maximum contraction. The assessor will match the participant's force and record the score.

Shoulder mobility will be measured by active shoulder internal and external rotation range of motion in both left and right arms using a Baseline digital inclinometer (Model 12-1057). The participant will be in supine with knees bent, with their shoulder at 90 degrees of abduction in the coronal plane. The elbow will be flexed to 90 degrees, forearm pronated and the shoulder fully supported in neutral horizontal positioning. The inclinometer will be aligned on the participant's forearm along the edge of the ulna in a vertical position. The assessor will instruct the participant to rotate elbow backwards (external rotation) as far as possible and

record the measurement, then return to vertical and ask the participant to rotate their forearm forwards (internal rotation) as far as possible and record the measurement.

Physical activity will be assessed over a 7-day period using an accelerometer (Actigraph wGT3x-BT) worn on an adjustable elastic belt on the right hip. The Actigraph has been successfully used to measure physical activity in large-scale population-based studies internationally.[44,45] The device is able to accurately estimate physical activity by measuring three dimensional body accelerations. More vigorous activities are associated with greater acceleration counts per minute and sedentary behaviour (e.g. sitting or lying) results in very few counts per minute. The measurement will be quantified as the average counts per minute during the time the accelerometer is worn. Thus the measurement will detect any increase in total daily physical activity (i.e., less time spent sitting). We will follow the recommendation that accelerometer-based data be collected over a one-week period to account for day-to-day variation in physical activity levels.[44] The accelerometers will be handed to participants at baseline and six month sessions and posted to participants at 12 months. Participants will be provided with clear instructions for use and telephone support will be available. Participants will be provided with padded reply paid preaddressed envelopes to return the devices to the research centre. The analyses will be adjusted for accelerometer wear time defined by 'off time'. Any period of greater than 60 minutes with no activity at all will be considered to be 'off time' and excluded from the analyses.

Physical activity will also be assessed using self-report data from the Incidental and Planned Exercise Questionnaire.[46] Attitudes to exercise will be assessed by selected questions from the Physical Activity Stages of Change questionnaire, the Exercise Self-Efficacy Scale and the Physical Activity Enjoyment Scale.[47-49] Fear of falling will be assessed using the Short

Falls Efficacy Scale International. This scale has been found to have good validity and reliability and is recommended for research and clinical purposes.[50,51] Health-related quality of life will be measured using the SF12v2 questionnaire which measures quality of life in the domains of physical function, role limitation, social function, pain, mental health, and vitality.[52] This measure can also be used to calculate the SF6D utility score which will be used to calculate quality adjusted life years (QALYs) for the economic evaluation,[53] scored using Australian preference weights.[54] Health-system and community-service contact will be collected on a monthly basis along with the falls calendars to enable calculation of health care costs for the economic analysis.

Recruitment procedures

Participants will be recruited using a variety of methods, including paid advertisements in local newspapers, media releases, radio interviews, distribution of flyers and other printed material promoting the study and presentations to community groups. Potential participants will call a project team member who will screen them for eligibility. A study information pack, which will include a participant information sheet, consent form, dates for sessions and approval form to request medical clearance, will be posted to eligible participants. On return of the completed consent form and session preferences, participants will be enrolled in the study. Medical clearance will be obtained prior to their participation in the study.

Randomisation procedures

After completing the baseline assessment and questionnaires, participants will be randomly allocated to either the lower limb or upper limb exercise groups. Randomisation will occur using a computer generated random number schedule with variable block sizes. The randomisation schedule will be developed by an investigator not involved in the recruitment

of participants and allocation to groups will occur after all baseline measures have been collected. People living in the same household will be treated as one unit and allocated to the same exercise program. Due to the nature of the exercise program, participants and program providers are unable to be blinded to group allocation. Outcome assessors will be blinded to the intervention allocation.

Statistical analysis including sample size calculations

Sample size

The required sample size of 576 will provide 80% power to detect as significant, at the 5% level, a 30% lower rate of falls for the lower limb intervention group participants than the upper limb intervention group participants (i.e., IRR = 0.70). Sample size calculations used the gennbreg command in Stata 13 and coefficients from previous studies: alpha (a measure of over-dispersion in the negative binomial regression model) was assumed to be 0.8 based on a previous RCT in a similar population.[55] We assumed the upper limb group rate of falls to be 0.85 falls/person year over the 12-month follow-up, which is comparable with the fall rates found in similar trials with community based samples.[56] The 0.70 value for IRR was chosen as this is comparable to the size of the effect on the rate of falls from other exercise interventions.[56] This sample size will also be sufficient to detect a 30% reduction in the proportion of fallers (upper limb proportion of fallers 40%, lower limb group proportion of fallers 28%) with 80% power and 15% loss to follow-up. The sample size of 576 participants will also be sufficient to detect a 10% between-group difference in the DASH total score and the secondary physical outcomes such as Short Physical Performance Battery (power= 90%, p= 0.05, SD=0.69, control group mean score score=0.178).

Data collection and management

Participant data will be collected by written survey questionnaires completed at workshops and via post, and by face to face physical assessments. Baseline questionnaires, postal fall calendars and Actigraph accelerometers will be provided to participants by the Program Manager and Project Officer during the measurement session in the week prior to randomisation. Follow-up questionnaires will be provided during the 3 and 6 month workshops. Actigraph accelerometers will also be provided to participants during the 6-month workshop. For the 12-month follow-up timepoint, questionnaires and Actigraph accelerometers will be posted to participants with postage paid return envelopes. Balance, strength and mobility assessments will be conducted by trained physiotherapists and exercise physiologists blinded to group allocation at the baseline measurement session and at 3 and 6 months' post randomisation during the workshop sessions. Workshops will be held in local community venues such as community centres and service clubs and the assessments will be administered in a private room in the community venue to ensure the privacy of the participants and to promote a quiet assessment space. To ensure blinding of assessors is maintained, measurements will be conducted in separate rooms in the community venues by assessors not involved in the delivery of the exercise interventions. Participants will be asked to not mention their exercise group allocation to the blinded assessors. All data will be entered onto a password protected database. Paper files will be stored in a locked filing cabinet in the office of an investigator. Access to data will be limited to authorised study staff. All publications associated with the results of the study will involve de-identified data, so participant confidentiality is maintained.

Data monitoring

The Research Manager will be notified within 12 hours of any research staff member witnessing or becoming aware of a participant reporting an adverse event. Participants will also be asked about the occurrence of adverse events in the questionnaire completed at 12 months post randomisation. A Data Monitoring Committee (DMC), independent from the study sponsor and competing interests, will be convened to monitor serious adverse events (SAE), in order to ensure the safety of participants. If a SAE occurs, the Research Manager will notify the DMC Chair within 48 hours.

Statistical analysis

The number of falls per person-year will be analysed using negative binomial regression models to estimate the between-group difference in fall rates after one year. Modified Poisson regression models will be used to compare groups on dichotomous outcome measures (proportion of fallers, proportion meeting physical activity guidelines).

Linear regression models will be used to assess the effect of group allocation on the continuously-scored measures (DASH questionnaire, strength, balance, physical activity, quality of life, fear of falling, upper limb pain and function, shoulder internal and external rotation force and range of movement, health and community service use), after adjusting for baseline scores.

Economic evaluation

The economic evaluations will be conducted from a health and community service provider perspective. Two economic evaluations will be conducted. The first will assess the cost-effectiveness of the lower limb program compared to the upper limb program in terms of

incremental cost per fall prevented, per extra person achieving a clinically meaningful (one-point) improvement in the SPPB and per QALY gained. The second will assess the cost effectiveness of the upper limb program compared to the lower limb program in terms of incremental cost per extra person achieving a clinically meaningful improvement in the DASH and per QALY gained.

Costs for the following categories will be included: implementing the lower limb program (e.g. staff costs, consumables); implementing the upper limb program; total health care costs (including fall-related health care resource use and inpatient costs); health and community service use from calendars and published estimates of relevant unit costs will be used to calculate total costs in each trial arm. Detailed supplementary data on costs of falls[57] and NSW Ministry of Health data[58] will assist with accurate costing of different types of falls and the costs of falls.

Using mean costs and mean health outcomes in each arm, the incremental cost effectiveness for each intervention above will be calculated; results will be plotted on a cost-effectiveness plane. Bootstrapping will be used to estimate a confidence interval around costs and health outcomes. One-way sensitivity analysis will be conducted around key variables, and a probabilistic sensitivity analysis will be conducted to estimate the joint uncertainty in all parameters; a cost-effectiveness acceptability curve (CEAC) will be plotted. A CEAC provides information about the probability that an intervention is cost-effective, given a decision maker's willingness to pay for each additional health outcome.

Dissemination

The results of this trial will be disseminated via peer-reviewed journal articles, presentations

at conferences and participant newsletters.

Discussion

There is strong evidence to support the use of exercise programs with a focus on balance and strength to reduce the risk of falling in older people.[4,5] Although evidence in support of exercise programs in reducing upper limb and shoulder pain is lacking, exercise is a common intervention for treating shoulder disorders in people of all ages.[21,30] Home-based exercise programs have been shown to be more acceptable to many older people than group-based exercise programs[7,8] with people from lower socioeconomic groups, older age groups and those with a recent fall reporting a greater interest in carrying out balance and strength training at home.[8] Access to a variety of options in terms of available balance and strength training exercise programs for older people may increase uptake and adherence among community-dwellers. The BEST at Home program provides an alternative method of participation in an exercise program for older people living in the community who would prefer to exercise in their own home or who are unable to access community-based exercise classes.

This trial will provide evidence about the effectiveness and cost-effectiveness of home-based exercise programs to prevent falls and upper limb dysfunction among older people. If the BEST at Home exercise programs are effective, there will be benefits to the individual in terms of improved balance, strength and mobility which will likely improve physical function and result in a better quality of life. There are also likely benefits to the community in terms of reduced fall-related injuries, fall-related health problems and upper limb dysfunction; this may, in turn, reduce demand on health and community services. If proven effective, this trial will provide a scalable population-level model for both an upper limb and lower limb

exercise program for older people which can be performed at home and implemented with existing health care services.

Conflict of interest declaration

The authors confirm there are no conflicting interests to declare.

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Figure 1 – Trial design

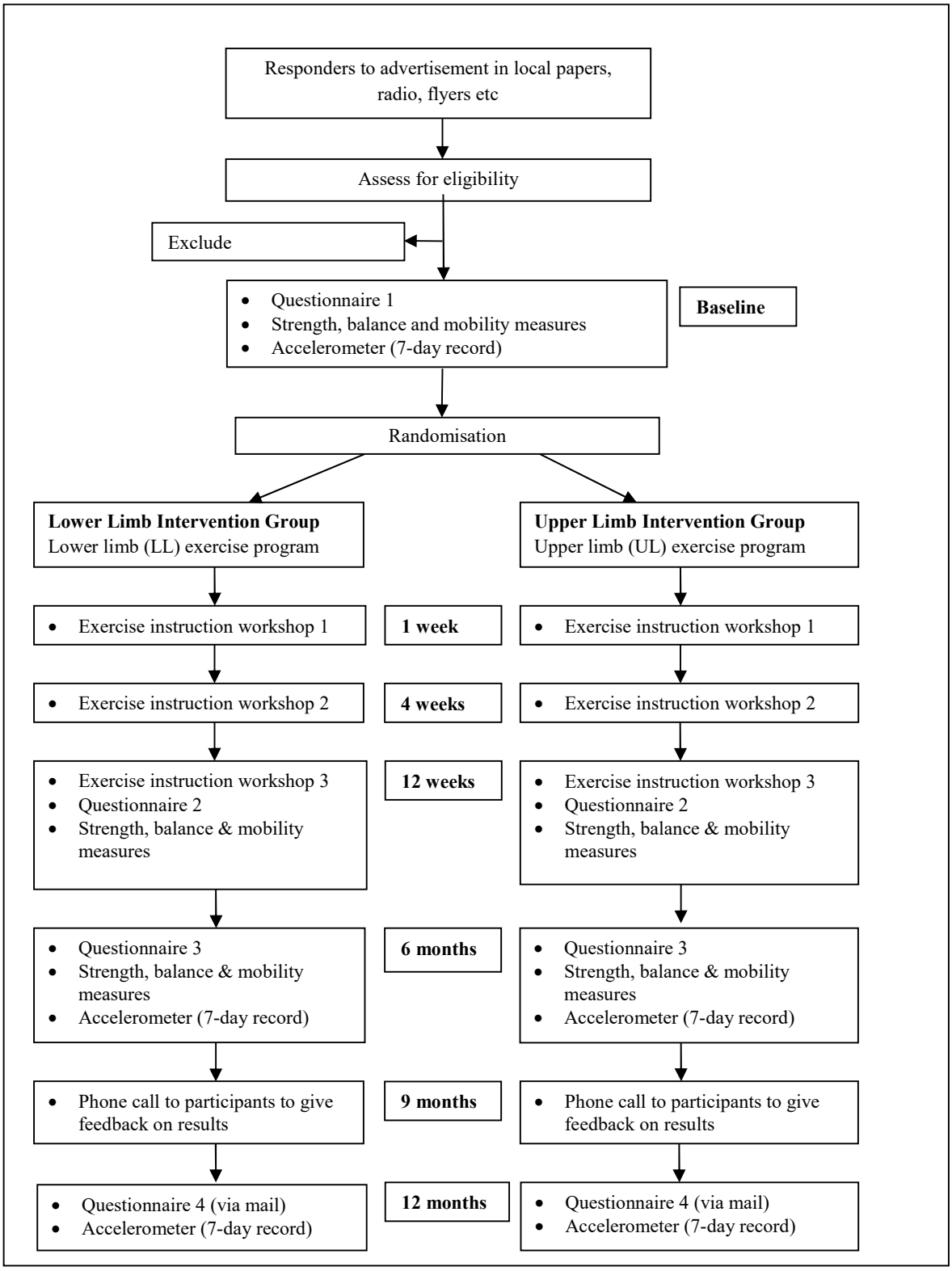

Table 1 Intervention description using the Template for Intervention Description and Replication (TIDieR) checklist

1. Brief name	Balance Exercise Strength Training (BEST) at Home trial
2. Why	Falls are a major and increasing public health issue. More than 25% of people 65 years and over fall at least once each year. Balance and strength training has been shown to reduce the risk of falling in older people. Upper limb dysfunction, including shoulder pain is also an important health issue for older people living in the community. Exercise is often used in the treatment of upper limb dysfunction, however little is known about the use of exercise in the prevention of upper limb dysfunction.
3. What materials	Participants in the lower limb exercise intervention will receive: - An exercise program designed to improve balance and strength in the lower limbs, including exercise instruction, manual and weights; - A booklet *Staying Active and On Your Feet* Participants in the upper limb exercise intervention will receive: - An exercise program designed to improve upper limb strength and mobility, including exercise instruction, manual, weights and exercise band
4. What procedures	For the lower limb exercise intervention - Three group-based exercise instruction sessions to implement and progress the exercises - Participants perform the exercises three times per week at home For the upper limb exercise intervention - Three group-based exercise instruction sessions to implement and progress the exercises - Participants perform the exercises three times per week at home
5. Who provided	Physiotherapists will deliver the exercise instruction.
6. How	The exercise instruction will be delivered in small groups of approximately 10 participants. Participants will be asked to perform the exercises at home three times per week.
7. Where	The intervention will be delivered to community dwelling people aged 65 years and over in the Illawarra and Shoalhaven regions of NSW, Australia.
8. When and how much	Exercise instruction sessions will be held in weeks 1, 4 and 12 and will last for approximately 1 hour. Participants will be asked to perform the exercises three times per week for 12 months at home.
9. Tailoring	For both interventions the exercises will be tailored to the participant's level of ability. The physiotherapist instructing the program will look at each participant's level of ability and adjust the exercises as required.

Chapter 4: Effectiveness of workshops to teach a home-based exercise program (BEST at Home) for preventing falls in community-dwelling people aged 65 years and over: a pragmatic randomised controlled trial

Chapter Four is presented in the format of the journal where it was published

Bates A, Furber S, Sherrington C, van den Dolder P, Ginn K, Bauman A, Howard K, Kershaw M, Franco L, Chittenden C, Tiedemann A. Effectiveness of workshops to teach a home-based exercise program (BEST at Home) for preventing falls in community-dwelling people aged 65 years and over: a pragmatic randomised controlled trial. *BMC Geriatrics*. 2022;22(1):366. doi:10.1186/s12877- 022-03050-2

Authorship contribution statement

As primary supervisor and co-author of the paper “Effectiveness of workshops to teach a home-based exercise program (BEST at Home) for preventing falls in community-dwelling people aged 65 years and over: a pragmatic randomised controlled trial”, I confirm that Amanda Macaulay (Bates) is the lead corresponding author and has made the primary contribution to this study in each of the following areas in collaboration with co-authors Furber S, Sherrington C, van den Dolder P, Ginn K, Bauman A, Howard K, Kershaw M, Franco L, Chittenden C, Tiedemann A:

- Conception and design of the research
- Data collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of the content

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

Preamble to Chapter Four

This chapter describes the results of the lower limb exercise component of the randomised control trial described in Chapter Three. The trial tested a lower limb home-based exercise program designed to prevent falls among adults aged 65 years and older living in the Illawarra and Shoalhaven areas of New South Wales, Australia. The exercises were based on the Otago Exercise Program and instruction was provided via small group-based workshops rather than individual home visits (as were provided in the original Otago Exercise Program).

We hypothesised that participants in the lower limb home-based exercise program would have a reduction in the rate of falls, while improving lower limb strength and balance and reducing fear of falling compared to the control group.

The upper limb exercise program was included to provide a relevant comparison condition and to allow evaluation of its specific effects on upper limb function. Its inclusion also served as an active control, enabling the lower limb program to be assessed against another structured, purposeful intervention rather than a passive or non-exercise control. This design ensures that any observed differences between programs can be attributed to the focus of the intervention rather than to general engagement in exercise. In this way, the study effectively incorporated two parallel trials within a single protocol.

BMC Geriatrics

RESEARCH

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Effectiveness of workshops to teach a home-based exercise program (BEST at Home) for preventing falls in community-dwelling people aged 65 years and over: a pragmatic randomised controlled trial

Amanda Bates[1*], Susan Furber[1,2,3], Cathie Sherrington[4,5], Paul van den Dolder[6], Karen Ginn[7], Adrian Bauman[5], Kirsten Howard[5], Michelle Kershaw[1], Lisa Franco[1], Cathy Chittenden[8] and Anne Tiedemann[4,5]

Abstract

Background: Falls are a significant public health issue. There is strong evidence that exercise can prevent falls and the most effective programs are those that primarily involve balance and functional exercises, however uptake of such programs is low. Exercise prescribed during home visits by health professionals can prevent falls however this strategy would be costly to deliver at scale. We developed a new approach to teach home exercise through group-based workshops delivered by physiotherapists. The primary aim was to determine the effect of this approach on the rate of falls among older community-dwelling people over 12 months. Secondary outcomes included the proportion of people falling, fear of falling, physical activity, lower limb strength, balance and quality of life.

Methods: A randomised controlled trial was conducted among community-dwelling people aged ≥65 in New South Wales, Australia. Participants were randomised to either the intervention group (exercise targeting balance and lower limb strength) or control group (exercise targeting upper limb strength).

Results: A total of 617 participants (mean age 73 years, ±SD 6, 64% female) were randomly assigned to the intervention group ($n = 307$) or control group ($n = 310$). There was no significant between-group difference in the rate of falls (IRR 0.91, 95% CI 0.64 to 1.29, $n = 579$, $p = 0.604$) or the number of participants reporting one or more falls (IRR 0.99, 95% CI 0.76 to 1.29, $n = 579$, $p = 0.946$) during 12 month follow-up. A significant improvement in the intervention group compared to control group was found for fear of falling at 3, 6 and 12 months (mean difference 0.50, 95% CI 0.2 to 0.8, $p = 0.004$; 0.39, 95% CI 0.001 to 0.8, $p = 0.049$; 0.46, 95% CI 0.006 to 0.9, $p = 0.047$, respectively), and gait speed at 3 months (mean difference 0.09 s, 95% CI 0.003 to 0.19, $p = 0.043$). No statistically significant between-group differences were detected for the other secondary outcomes.

Conclusions: There was no significant intervention impact on the rate of falls, but the program significantly reduced fear of falling and improved gait speed. Other exercise delivery approaches are needed to ensure an adequate intensity of balance and strength challenge and dose of exercise to prevent falls.

*Correspondence: amanda.bates@health.nsw.gov.au
[1] Health Promotion Service, Illawarra Shoalhaven Local Health District, Wollongong, NSW, Australia
Full list of author information is available at the end of the article

Keywords: Accidental falls, Aged, Exercise, Falls prevention, Randomised controlled trial

Introduction

Falls are a significant and increasing public health issue. In New South Wales (NSW), Australia, more than 25% of people over the age of 65 years fall at least once each year [1]. Falls are one of the most common causes of injuries among older people [2]. Consequences of falls include serious injury, hospitalisation [1], fear of falling [3] and reduced quality of life [4].

A recent Cochrane systematic review and meta-analysis [5] found strong evidence that exercise programs can reduce the rate of falls and that the most effective exercise programs are those that primarily involve balance and functional exercises. The World Health Organisation (WHO) Guidelines on Physical Activity and Sedentary Behaviour (2020) recommend that older adults do functional balance and strength training on three or more days per week, to enhance functional capacity and prevent falls [6]. Many older adults do not meet the exercise recommendations to prevent falls [7]. There is a need to promote uptake and ongoing participation in exercise programs with balance and strength components that are easily accessible to older adults.

Exercise programs for older people can be effective in preventing falls if delivered in either a group or individual format [8, 9]. Individual programs that are carried out at home have been reported to be more appealing to some older people due to their greater convenience, accessibility and lower cost [10, 11]. People who are older and at a higher risk of falls are more likely to prefer home-based exercise programs compared to group-based classes [11, 12]. Home-based strength and balance training has also been shown to be safe and effective in improving balance and strength [13–15]. The Otago Exercise Programme is an effective home-based fall prevention program involving strength and balance exercises [13], which reduces the number of falls and injuries from falls in older community-dwelling adults [13, 16, 17]. The Otago Exercise Programme was originally delivered by physiotherapists or trained community nurses via individual home visits. Bates and colleagues piloted a new method of delivery for the Otago Exercise Programme that used group sessions to deliver the exercise instruction instead of individual home visits [18]. This pilot program increased strength and balance and non-significantly reduced falls in a pre-post study (no control group) [18]. This pragmatic approach that could be scaled up for broader implementation warranted further evaluation in a larger study with a control group.

The primary aim of the current study was to determine the effectiveness of a home-based exercise program (BEST at Home – lower limb) taught through workshops in community venues delivered by physiotherapists and aimed at preventing falls among community-dwelling people aged 65 years and over. The secondary aims were to determine the effect of the BEST at Home program on the proportion of people falling, fear of falling, physical activity, lower limb strength, balance, attitudes to exercise, quality of life, cost-effectiveness and to describe the program acceptability to participants.

Methods

Study design

We conducted a pragmatic randomised controlled trial with two parallel arms. After completing the baseline assessment and questionnaires, participants were randomly assigned to either the intervention (lower limb) or control (upper limb) exercise program. Randomisation order was determined using a computer-generated random number schedule (hosted on REDCap) with variable block sizes of 2–6, developed by an investigator not involved in recruitment for the trial. People living in the same household were treated as one unit and allocated to the same exercise program to avoid possible contamination of interventions. Due to the nature of the exercise program, participants and program providers were unable to be blinded to group allocation. Data for the primary outcome of falls was self-reported by participants, however the person following up primary outcome data with participants was blinded to group allocation. Secondary outcomes were collected by assessors who were blinded to the group allocation. Participants were instructed not to inform the assessors of their intervention group. Ethical approval was obtained from the University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee (HE14/279 and HREC/14/WGONG/50). All methods were performed in accordance with the relevant guidelines and regulations. A detailed protocol describing the design and methods of the study has been published [19]. The study reporting is in accordance with the Consolidated Standards of Reporting (CONSORT) [20]. The trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12615000865516) on 19/08/2015.

Participants

Participants were community-dwelling adults aged 65 years and older residing in the Illawarra and Shoalhaven Local Health District, New South Wales, Australia. They were recruited using a variety of methods, including paid advertisements in local newspapers, media releases, radio interviews, distribution of flyers and other printed material promoting the study and presentations to community groups. Inclusion criterion was community-dwelling and aged 65 years or over. Participants were screened for eligibility over the telephone and were considered ineligible if they had any of the following: cognitive impairment (assessed by a Memory Impairment Screen score of less than 5) [21]; inability to walk 10 m despite assistance from a walking aid; insufficient English language skills to read and understand program materials; a progressive neurological disease (e.g. Parkinson's disease, multiple sclerosis); fracture or joint replacement within the last 6 months; a medical condition precluding exercise (e.g. unstable cardiac disease, uncontrolled hypertension, uncontrolled metabolic diseases); unable to obtain medical clearance (as determined by their General Practitioner) and currently participating in an exercise program two or more times per week that is similar to either the upper limb or lower limb exercise program.

Intervention group

Participants allocated to the intervention group received a home-based exercise program to improve balance and strength in the lower body. This program was based on the Otago Exercise Programme [13, 22] and included 17 balance and strength exercises, such as knee extension and knee flexion, hip abduction, calf raises, toes raises, sit to stand, semi squats from a standing position, tandem stand, tandem walk, sideways walking, backwards walking, heel walking, toe walking, one leg stand, and walking and turning around. Participants were instructed to perform 10–20 repetitions of the exercises, three times per week at home. Participants were provided with an ankle cuff weight (0.5 kg – 5 kg), with the weight determined by the physiotherapist at the first session. A home exercise manual containing diagrams and descriptions of the exercises and a copy of 'Staying Active and On Your Feet', a booklet produced by NSW Health about preventing falls [23] was provided to all participants. Participants were shown how to make each exercise progressively more difficult and were encouraged to make the balance exercises more challenging as they continued the program (see Table 1 TIDieR checklist).

Table 1 Intervention description using the Template for Intervention Description and Replication (TIDieR) checklist

Checklist item	
1. Brief name	Balance Exercise Strength Training (BEST) at Home (lower limb) trial
2. Why	Falls are a major and increasing public health issue. More than 25% of people 65 years and over fall at least once each year. Balance and strength training has been shown to reduce the risk of falling in older people.
3. What materials	Participants in the intervention group received: - an exercise program designed to improve balance and strength in the lower limbs (including exercise instruction, printed manual and weights); - a booklet on preventing falls titled 'Staying active and on your feet' Participants in the control group received: - an exercise program designed to improve upper limb strength and mobility (including exercise instruction, printed manual, weights and exercise band)
4. What procedures	Both the intervention and control groups received three group-based exercise instruction sessions and three measurement sessions.
5. Who provided	Physiotherapists delivered the exercise instruction. Physiotherapists and exercise physiologists conducted the measurements.
6. How	The exercise instruction was delivered face to face in small groups of approximately 10 participants.
7. Where	In the community of the Illawarra and Shoalhaven regions, NSW, Australia.
8. When and how much	Exercise instruction sessions were held in weeks 1, 4 and 12 (1 h duration). Participants were asked to perform the exercises three times per week for 12 months. The first measurement session occurred at baseline before the participant was randomised. The second and third measurement sessions were held at 12 weeks and 6 months. Final questionnaires were posted to participants at 12 months.
9. Tailoring	Exercises were tailored by the physiotherapist for each participant, to meet their level of ability.
10. Modifications	No modifications were made.
11. How well (planned)	Adherence to the exercise program was assessed by self-reported exercise sessions, which were marked on calendars (and returned monthly)
12. How well (actual)	Participants were asked to perform the exercises 3 times per week. Participants in the intervention group completed an average of 94 sessions over the 12 month period (less than twice per week). Participants in the control group completed an average of 104 sessions over the 12 month period (twice per week).

Control group

The control group received an upper limb exercise program (BEST at Home – upper limb) designed by members of the research team to improve upper limb strength, mobility, and function. The upper limb exercise program was a set of eight exercises, which included arm raises, internal and external shoulder rotation, elbow flexion and extension, shoulder press, chest press and shoulder row. A pair of dumbbell weights (600 g – 3 kg) and an elastic exercise band (light, medium, heavy or extra heavy resistance) were provided, with the exercise level determined by the supervising physiotherapist. A home exercise program manual containing diagrams and descriptions of the exercises was provided. Participants were instructed to perform 10 repetitions of each exercise during three exercise sessions per week at home. All exercises in the upper limb program were performed in a seated position, to reduce the likely impact on balance and fall prevention and hence to reduce the contamination effect with respect to the lower limb exercise program.

Both groups

Both exercise programs were delivered by two experienced physiotherapists in three group workshops. The workshops were run in local community centres or clubs and contained approximately 10 participants. Exercise instruction workshops occurred at weeks 1, 4 and 12, and were one hour in duration. The program was tailored to each participant's level of ability. At each workshop, the exercises were reviewed, techniques were corrected, and exercises adjusted or progressed by the supervising physiotherapist, according to the ability of each participant.

Outcome measures

The primary outcome was the rate of falls, recorded with monthly calendars for a 12 month period, post-randomisation [24]. A fall was defined as 'an unexpected event in which the participants come to rest on the ground, floor, or lower level' [24]. Falls were recorded using monthly calendars for a 12-month period after randomisation. Calendars were returned in reply paid, preaddressed envelopes. Participants who did not return their calendars were telephoned to ask about falls for that month. Participants who reported a fall were telephoned to confirm the fall and obtain details about fall location, resulting injuries and what treatment was sought. There were several secondary outcomes. Fear of falling was assessed using the short form Falls Efficacy Scale International (FES-I) [25, 26]. Quality of life was assessed with the self-report SF12v2 [27]. Lower limb strength and balance were assessed with the Short Physical Performance Battery (SPPB) [28], the alternate step test [29] and a knee extension (quadriceps) strength test [30]. The assessments of strength and balance were conducted by Physiotherapists and trained research assistants who were blinded to group allocation. Physical activity (including daily step count, counts per minute and minutes of moderate to vigorous physical activity) was measured with an Actigraph accelerometer (model wGT3x-BT) worn at the waist [31, 32]. Accelerometer data were collected over a one-week period to account for day-to-day variation in physical activity levels. Acceptable wear time was defined as a minimum of 4 days of 10 h or more per day. Activity counts per second were collected at a sampling frequency of 30 Hz and reintegrated to 60s epochs for data analysis. Physical activity was also measured using self-report data from the Incidental and Planned Exercise Questionnaire [33]. Paper-based questionnaires were self-completed during sessions at baseline, 12 weeks and 6 months; and via paper postal questionnaires at 12 months. The proportion of people falling in the intervention and control groups was determined by the monthly falls calendars.

Participants also completed a baseline questionnaire that included questions about sociodemographic details, number of prescription medications, number of comorbidities, history of falls, fear of falling (short FES-I), and self-rated balance perception. Attitudes to exercise were assessed by selected questions from the Physical Activity Stages of Change questionnaire, the Exercise Self-Efficacy Scale and the Physical Activity Enjoyment Scale [34–36]. In order to measure program adherence, participants were asked to record the days that they completed the exercises on the falls calendars that they returned each month.

Data analysis

The number of falls per person-year were analysed using negative binomial regression models to estimate the between-group difference in fall rates after 1 year (primary outcome). Days of follow up was included as an exposure variable in the negative binomial regression analysis. Modified Poisson regression models were used to compare groups on dichotomous outcome measures (proportion of fallers). Linear regression models were used to assess the effect of group allocation on the continuously-scored measures of strength, balance, physical activity (self-report and accelerometer), quality of life (SF-12), fear of falling (short FES-I), after adjusting for baseline scores. For variables that were not normally distributed (short FES-I, SF-12, moderate vigorous physical activity (MVPA), planned physical activity, total walking, SPPB, standing balance, single leg stance) change scores from baseline to follow up were analysed. Separate linear regression analyses were performed for each time point for continuous measures. Interaction terms in the model were used to assess for differential intervention effects by

age, sex (male versus female), upper limb dysfunction or previous falls. Statistical significance was set at $p < 0.05$. The data analysis for the primary and secondary outcomes was undertaken blinded to the group allocation and used an intention-to-treat approach. Sample size calculations suggested that 576 participants would provide 80% power to detect as significant, at the 5% level, a 30% lower rate of falls for the intervention group participants than the control group participants (i.e., incidence rate ratio (IRR) = 0.70) with a 15% loss to follow up. The sample size calculation used the nbpower user written command in Stata. StataCorp. 2017 (Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). We assumed the upper limb group rate of falls to be 0.85 falls/person year over the 12-month follow-up, which is comparable with the fall rates found in similar trials with community based samples [37]. A sensitivity analysis was conducted for the primary outcome to account for the clustering of household participants.

Results

Participants

Recruitment occurred between September 2015 and May 2017. Follow up questionnaires were completed in May 2018. The flow of participants through the study is shown in Fig. 1. A total of 953 participants were screened for eligibility, 308 declined to participate and 28 did not meet the inclusion criteria. A total of 617 participants (mean age 73.1 years, SD 6.0, 63.7% female) were randomly assigned to the intervention group ($n = 307$) or control group ($n = 310$). Baseline characteristics of participants is presented in Table 2. The participants in the two groups were well-matched at baseline (Table 2).

Primary outcome

During the 12 month study period, 157 people (27% of participants who returned at least one calendar) reported 267 falls. In the intervention group 79 participants reported 138 falls and in the control group 78 participants reported 129 falls. There was no difference between the rate of falls in the intervention group compared to the control group (IRR 0.91, 95% CI 0.64 to 1.29, $p = 0.604$, $n = 579$). A sensitivity analysis conducted to adjust for clustering of households found similar results, with no difference in the rate of falls in the intervention group compared to the control group (IRR 0.91, 95% CI 0.63 to 1.32, $p = 0.624$, $n = 579$). Frequencies and percentages of self-reported falls are presented in Table 3. Participants returned an average of 10 months of calendars. A total of 424 (69%) participants completed all 12 months of falls calendars.

Secondary outcomes

Table 4 shows the baseline and follow-up scores for the secondary outcomes. A significant improvement in the intervention group compared with the control group was found for fear of falling (measured by the FES-I) at 3, 6 and 12 months (mean difference = 0.50, 95% CI 0.2 to 0.8, $p = 0.004$; mean difference = 0.39, 95% CI 0.001 to 0.8, $p = 0.049$; mean difference = 0.46, 95% CI 0.006 to 0.9, $p = 0.047$), and gait speed (measured by the 4 m walk) at 3 months (mean difference = 0.09 s, 95% CI 0.003 to 0.19, $p = 0.043$). There were no significant between-group differences in physical activity (accelerometer and self-report), quality of life (SF-12), SPPB, sit to stand, balance, alternate step test, leg strength and gait speed (at 6 months). There was no difference in the proportion of people falling in the intervention and control groups (IRR 0.99, 95% CI 0.76 to 1.29, $p = 0.946$), as demonstrated by the number of participants reporting one or more falls during the 12 month follow up (Table 3). The cost-effectiveness of the intervention will be reported separately.

Planned sub-group analysis for the primary outcome

In planned sub-group analyses, there was no evidence of statistically significant differential effects of the intervention on the primary outcome of falls by age ($p = 0.936$), sex (male versus female, $p = 0.680$), having fallen in the 12 months prior to baseline ($p = 0.460$) or upper limb dysfunction at entry to the trial, determined by a DASH score > 15 at baseline ($p = 0.125$) [38]. Analysis of the impact within subgroups suggested greater intervention effects in those who had fallen in the past year than those who had not (IRR 0.78, 95% CI 0.41 to 1.51, $p = 0.462$ in those who had fallen 1 or more times, IRR 1.02, 95% CI 0.69 to 1.50, $p = 0.931$ in those who had not fallen in the past year). Further exploratory analyses suggested greater intervention effects in those who had fallen two or more times in the year prior to the intervention (IRR 0.67, 95% CI 0.26 to 1.69, $p = 0.394$ in those who had fallen 2 or more times, IRR 1.00, 95% CI 0.70 to 1.42, $p = 0.999$ in those who fell 0–1 times in the past year) but these differences did not reach statistical significance ($p = 0.340$).

Adherence with the program

Attendance was recorded at the exercise instruction sessions which were held at weeks 1, 4 and 12. In the intervention group, 294 (96%) participants attended week 1, 260 (85%) attended week 4 and 242 (79%) attended week 12 sessions. In the control group, 298 (96%) participants attended week 1, 260 (84%) attended week 4 and 241

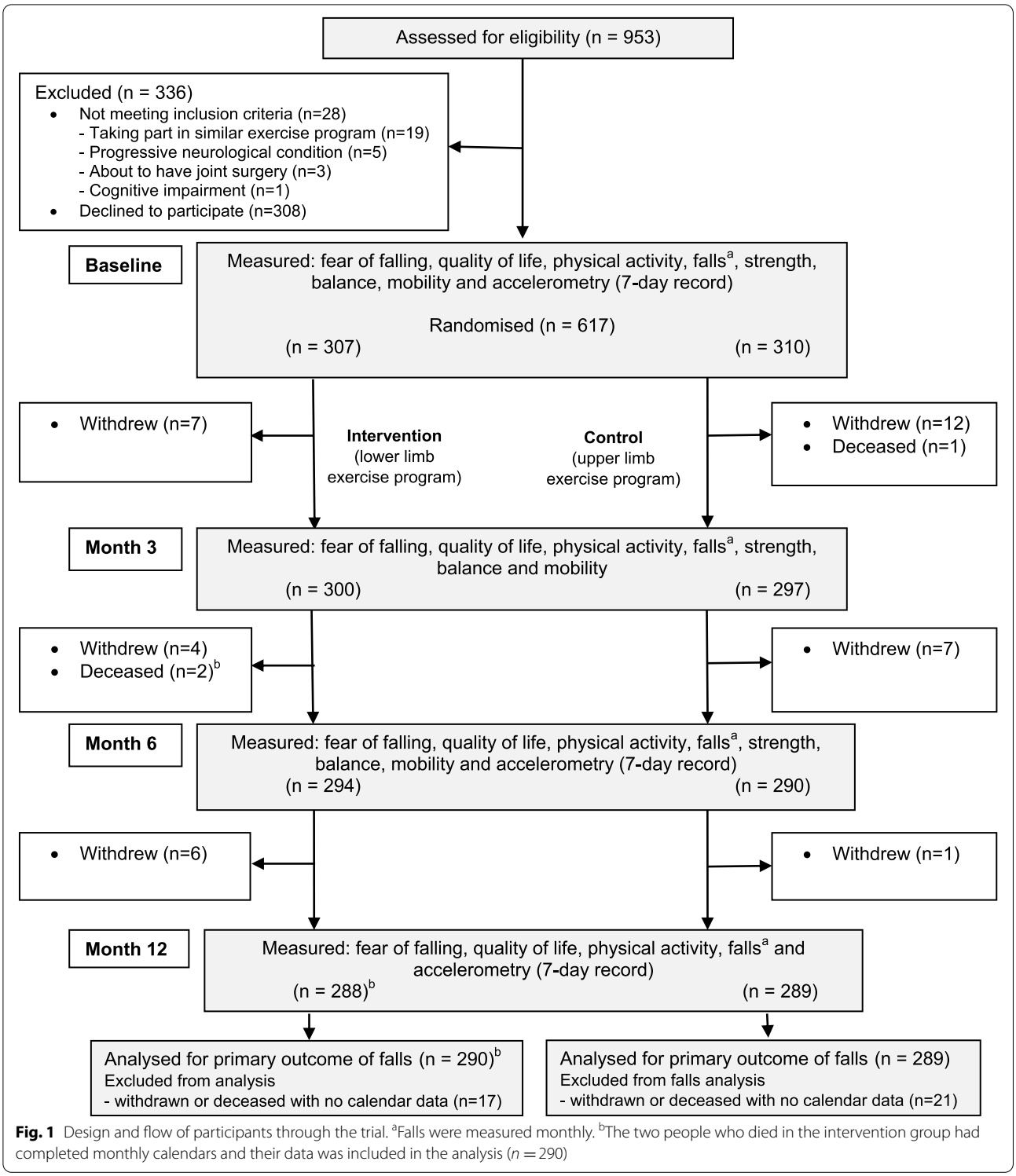

Fig. 1 Design and flow of participants through the trial. [a]Falls were measured monthly. [b]The two people who died in the intervention group had completed monthly calendars and their data was included in the analysis ($n = 290$)

(78%) attended week 12 sessions. In the intervention group, 279 (91%) participants attended two or more exercise instruction sessions. In the control group, 280 (90%) participants attended two or more exercise instruction sessions.

Participants in the intervention group reported completing the exercises less than twice per week, with an average of 94 (SD 63, range 0–287) exercise sessions over the 12 month period. Participants in the control group reported completing the exercises twice per

Table 2 Characteristics of participants at baseline

Characteristics	Intervention	Control	All
Age (years), mean (SD)	72.9 (6.2) $n=307$	73.2 (5.8) $n=310$	73.1 (6.0) $n=617$
Female: *n (%)*	196 (63.8) $n=307$	197 (63.6) $n=310$	393 (63.7) $n=617$
Lives alone: *n (%)*	89 (29.0) $n=307$	97 (31.3) $n=310$	186 (30.2) $n=617$
Fallen in the past 12 months: *n (%)*	80 (26.1) $n=307$	86 (27.7) $n=310$	166 (26.9) $n=617$
Self-rated balance fair/poor: *n (%)*	99 (32.6) $n=304$	96 (31.2) $n=308$	195 (31.9) $n=612$
Self-rated fear of falling $\geq$ moderate: *n (%)*	79 (25.7) $n=307$	72 (23.4) $n=308$	151 (24.6) $n=615$
Total medications (n), mean (SD)	3.0 (2.6) $n=304$	3.3 (2.7) $n=305$	3.1 (2.7) $n=609$
Medical conditions (0–17)[a], mean (SD)	2.8 (1.9) $n=307$	2.8 (2.0) $n=310$	2.8 (1.9) $n=617$
Arthritis: *n (%)*	173 (58.3) $n=297$	181 (58.6) $n=309$	354 (58.4) $n=606$
Osteoporosis: *n (%)*	66 (21.7) $n=304$	57 (18.6) $n=307$	123 (20.1) $n=611$
Diabetes: *n (%)*	26 (8.5) $n=306$	32 (10.4) $n=307$	58 (9.5) $n=613$
Depression: *n (%)*	51 (16.8) $n=303$	48 (15.8) $n=303$	99 (16.3) $n=606$
Self-report physical activity, hours/week[b]: mean (SD)	33.4 (19.1) $n=306$	34.3 (19.2) $n=309$	33.9 (19.1) $n=615$
SF12v2: physical composite score	48.0 (7.7) $n=304$	47.8 (7.4) $n=298$	47.9 (7.6) $n=602$
SF12v2: mental composite score	53.4 (5.7) $n=304$	53.6 (5.4) $n=298$	53.5 (5.6) $n=602$
Short FES-I, mean (SD)	9.7 (3.3) $n=307$	9.4 (2.9) $n=309$	9.6 (3.1) $n=616$
Average daily step count, steps, mean (SD)	5725.9 (2424.6) $n=297$	5539.6 (2394.5) $n=288$	5634.2 (2409.5) $n=585$
MVPA, minutes/day, mean (SD)	18.9 (17.4) $n=297$	17.2 (16.8) $n=288$	18.0 (17.1) $n=585$

Abbreviations: *FES-I* Falls Efficacy Scale-International, *MVPA* moderate vigorous physical activity

[a] Possible medical conditions included: arthritis, osteoporosis, asthma, chronic obstructive pulmonary disease, angina, heart disease, heart attack, neurological disease, stroke/transient ischaemic attack, peripheral vascular disease, diabetes mellitus, upper gastrointestinal disease, depression, anxiety/panic disorder, visual impairment, hearing impairment, degenerative disc disease

[b] Measured using the Incidental and Planned Exercise Questionnaire (IPEQ)

Table 3 Number of participants falling and total number of falls during 12 month follow up

Falls	All ($n=579$)	Intervention ($n=290$)	Control ($n=289$)	Unadjusted IRR* (95% CI)
Number of falls, n	267	138	129	0.91 (0.64 to 1.29), $p=0.604$[a]
Falls per participant, mean (SD), median (min-max)	0.46 (1.03), 0 (0–12)	0.48 (1.14), 0 (0–12)	0.45 (0.91), 0 (0–5)	
Frequency of falls, n (%)				
0	422 (72.9)	211 (72.8)	211 (73)	
1	102 (17.6)	51 (17.6)	51 (17.6)	
2	27 (4.7)	16 (5.5)	11 (3.8)	
3	14 (2.4)	5 (1.7)	9 (3.1)	
≥ 4	14 (2.4)	7 (2.4)	7 (2.4)	
1+ falls	157 (27.1)	79 (27.2)	78 (27)	0.99 (0.76 to 1.29), $p=0.946$[b]
Follow up, days, mean (SD)	311.8 (103.6)	306.6 (105.7)	317.1 (101.4)	
Falls indoors, n (%)	90 (33.7)	50 (36.2)	40 (31)	
Falls outdoors, n (%)	177 (66.3)	88 (63.8)	89 (69)	
Falls with fractures, n (%)	16 (6)	12 (8.7)	4 (3.1)	
Falls requiring hospital admission, n (%)	10 (3.7)	5 (3.6)	5 (3.9)	

[a] Between-group difference from negative binomial regression models comparing rates between groups adjusted for exposure: days of follow-up

[b] Between-group difference from Poisson regression models comparing proportions between groups

[*] *IRR* Incidence rate ratio

[**] 38 participants with no calendar data removed for analysis

Table 4 Intervention effects on secondary outcomes

Outcome measure	Intervention Mean (SD), *n*	Control Mean (SD), *n*	Mean difference (95% CI)	*P* value
Falls Efficacy Scale-International (7–28)[b c]				
Baseline	9.7 (3.3) *n* = 307	9.4 (2.9) n = 309		
3 months	9.1 (2.7) *n* = 262	9.2 (2.7) *n* = 250	0.50 (0.2–0.8)	0.004*
6 months	9.2 (2.8) *n* = 243	9.3 (2.9) *n* = 250	0.39 (0.001–0.8)	0.049*
12 months	9.1 (2.7) *n* = 231	9.4 (2.9) *n* = 235	0.46 (0.006–0.9)	0.047*
Quality of life – physical (SF12 physical component summary score)[a c]				
Baseline	48.0 (7.7) *n* = 304	47.8 (7.4) *n* = 298		
3 months	48.5 (7.6) *n* = 257	48.1 (7.0) *n* = 243	−0.28 (−1.2–0.6)	0.534
6 months	48.0 (8.2) *n* = 238	47.7 (7.8) *n* = 244	0.26 (− 0.8–1.3)	0.633
12 months	48.5 (7.6) *n* = 227	47.2 (8.7) *n* = 228	−1.1 (−2.3–0.008)	0.052
Quality of life – mental (SF12 mental component summary score)[a c]				
Baseline	53.4 (5.7) *n* = 304	53.6 (5.4) *n* = 298		
3 months	54.1 (5.6) *n* = 257	54.4 (5.3) *n* = 243	−0.1 (−1.1–0.8)	0.808
6 months	54.2 (5.3) *n* = 238	54.1 (5.1) *n* = 244	−0.7 (−1.6–0.3)	0.185
12 months	54.4 (5.0) *n* = 227	54.2 (4.8) *n* = 228	−0.1 (−1.1–0.8)	0.824
Physical activity, accelerometer (counts per minute)[a]				
Baseline	239.4 (110.6) *n* = 297	229.7 (103.4) *n* = 288		
6 months	245.5 (111.0) *n* = 230	238.4 (112.9) *n* = 236	0.4 (−14.1–14.8)	0.960
12 months	248.6 (111.0) *n* = 205	245.5 (119.1) *n* = 193	3.2 (−10.7–17.0)	0.653
Daily steps, measured with accelerometer*(n)*[a]				
Baseline	5726 (2425) *n* = 297	5540 (2394) *n* = 288		
6 months	5957 (2653) *n* = 231	5689 (2337) *n* = 236	−105 (− 429–219)	0.525
12 months	5958 (2532) *n* = 205	5916 (2638) *n* = 193	90 (−223–402)	0.572
Moderate-vigorous physical activity, minutes/day (measured with accelerometer)[a c]				
Baseline	18.9 (17.4) *n* = 297	17.2 (16.8) *n* = 288		
6 months	20.0 (18.1) *n* = 231	17.6 (17.1) *n* = 236	−0.4 (−3.1–2.3)	0.775
12 months	19.8 (18.0) *n* = 205	19.0 (18.6) *n* = 193	0.3 (−2.1–2.8)	0.785
Total physical activity, hours per week[a d]				
Baseline	33.4 (19.1) *n* = 306	34.3 (19.2) *n* = 309		
3 months	33.4 (19.4) *n* = 260	33.1 (18.1) *n* = 247	−1.1 (−3.6–1.5)	0.412
6 months	31.7 (17.3) *n* = 244	33.0 (17.6) *n* = 250	0.9 (−1.7–3.5)	0.494
12 months	31.3 (16.7) *n* = 229	32.5 (17.6) *n* = 235	0.9 (−1.7–3.6)	0.491
Planned physical activity (excluding walking), hours per week[a c d]				
Baseline	2.3 (3.8) *n* = 307	2.2 (3.4) *n* = 310		
3 months	2.8 (3.8) *n* = 262	2.7 (3.1) *n* = 251	−0.2 (− 0.8–0.5)	0.575
6 months	2.7 (3.6) *n* = 244	2.4 (2.9) *n* = 250	−0.04 (− 0.7–0.6)	0.895
12 months	2.1 (3.1) *n* = 234	2.1 (3.5) *n* = 237	0.2 (−0.4–0.9)	0.514
Total walking, hours per week[a c d]				
Baseline	4.7 (5.6) *n* = 307	4.6 (4.8) *n* = 310		
3 months	5.3 (6.7) *n* = 261	5.0 (4.7) *n* = 249	−0.2 (−1.2–0.8)	0.702
6 months	4.5 (4.2) *n* = 242	4.8 (5.1) *n* = 250	0.4 (−0.5–1.3)	0.350
12 months	5.1 (5.6) *n* = 234	5.0 (6.1) *n* = 237	−0.03 (−1.1–1.0)	0.951
Incidental physical activity (including walking), hours per week[a d]				
Baseline	28.4 (18.2) *n* = 306	29.3 (17.7) *n* = 309		
3 months	27.7 (17.4) *n* = 261	27.4 (16.6) *n* = 246	−0.8 (−3.1–1.6)	0.519
6 months	26.2 (16.6) *n* = 243	28.2 (16.9) *n* = 246	1.5 (−1.0–4.0)	0.245
12 months	25.9 (16.0) *n* = 229	27.3 (16.2) *n* = 235	0.87 (−1.6–3.3)	0.487
Body Mass Index (BMI), kg/m^2				
Baseline	28.7 (5.2) *n* = 307	28.4 (5.1) *n* = 309		

Table 4 (continued)

Outcome measure	Intervention Mean (SD), *n*	Control Mean (SD), *n*	Mean difference (95% CI)	*P* value
3 months	28.1 (5.1) *n* = 243	27.9 (4.8) *n* = 239	0.15 (−0.05–0.4)	0.132
6 months	28.3 (5.0) *n* = 209	28.1 (5.0) *n* = 213	−0.07 (− 0.3–0.1)	0.525
Short physical performance battery, 0-12[a c]				
Baseline	10.9 (1.5) *n* = 307	10.8 (1.5) *n* = 309		
3 months	11.1 (1.4) *n* = 244	10.9 (1.3) *n* = 239	−0.06 (−0.3–0.1)	0.537
6 months	11.2 (1.4) *n* = 209	11.3 (1.1) *n* = 213	0.17 (−0.04–0.39)	0.108
Short physical performance battery-continuous summary performance score (CSPS), 0-3[c]				
Baseline	2.52 (0.22) *n* = 307	2.50 (0.23) *n* = 309		
3 months	2.55 (0.23) *n* = 244	2.53 (0.19) *n* = 239	−0.01 (−0.04–0.02)	0.522
6 months	2.56 (0.24) *n* = 208	2.57 (0.17) *n* = 213	0.03 (−0.002–0.06)	0.070
Sit to stand, time for 5 sit to stands, sec[b]				
Baseline	11.8 (3.5) *n* = 300	12.0 (3.4) *n* = 303		
3 months	11.0 (3.6) *n* = 235	11.4 (3.4) *n* = 234	0.15 (−0.35–0.66)	0.548
6 months	10.4 (3.6) *n* = 200	11.0 (4.2) *n* = 211	0.12 (−0.48–0.73)	0.688
Gait speed, time to walk 4 m, sec[b]				
Baseline	2.8 (0.7) *n* = 307	2.9 (0.8) *n* = 309		
3 months	2.6 (0.7) *n* = 244	2.8 (0.6) *n* = 239	0.09 (0.003–0.19)	0.043*
6 months	2.7 (0.6) *n* = 208	2.8 (0.6) *n* = 213	−0.01 (−0.1–0.08)	0.819
Standing balance, sum of feet together, semi-tandem, tandem stance times, sec, 0-30[a c]				
Baseline	29.0 (2.9) *n* = 307	28.7 (3.5) *n* = 309		
3 months	29.3 (2.3) *n* = 243	28.8 (2.9) *n* = 239	−0.19 (−0.71–0.32)	0.461
6 months	29.3 (2.8) *n* = 209	29.5 (1.7) *n* = 213	0.51 (−0.0002–1.0)	0.050
Single leg stance time, sec, 0-10[a c]				
Baseline	8.4 (2.7) *n* = 259	8.3 (2.8) *n* = 249		
3 months	9.0 (2.3) *n* = 216	8.7 (2.3) *n* = 192	−0.32 (−0.86–0.22)	0.244
6 months	9.2 (2.0) *n* = 185	8.9 (2.3) *n* = 190	−0.21 (− 0.77–0.35)	0.463
Alternate step test, time for 8 steps onto 18 cm step[b]				
Baseline	8.3 (2.5) *n* = 302	8.4 (2.1) *n* = 302		
3 months	7.7 (2.4) *n* = 236	8.1 (2.1) *n* = 237	0.26 (−0.06–0.58)	0.112
6 months	7.3 (2.1) *n* = 206	7.7 (2.3) *n* = 211	0.23 (−0.11–0.57)	0.189
Knee extension strength, right leg, kg[a]				
Baseline	16.1 (7.7) *n* = 307	14.6 (6.7) *n* = 309		
3 months	17.4 (7.5) *n* = 244	16.5 (6.6) *n* = 239	−0.55 (−1.72–0.63)	0.361
6 months	17.6 (7.8) *n* = 207	16.2 (7.6) *n* = 211	−0.60 (−1.86–0.65)	0.344
Knee extension strength, left leg, kg[a]				
Baseline	15.4 (7.4) *n* = 305	14.1 (6.8) *n* = 309		
3 months	16.9 (7.1) *n* = 240	15.8 (7.0) *n* = 239	−0.85 (−2.04–0.34)	0.160
6 months	16.6 (7.1) *n* = 206	15.2 (6.6) *n* = 212	−1.05 (−2.20–0.10)	0.072

[a] Higher scores reflect better performance

[b] Lower scores reflect better performance

[c] Skewed distribution

[d] Self-report measure using the Incidental and Planned Exercise Questionnaire (IPEQ)

[*] Significant outcome

week, with an average of 104 (SD 69, range 0–371) exercise sessions over the 12 month period, as determined by the exercise sessions recorded on the monthly calendars.

Acceptability of the intervention

Participants completed survey questions on their impressions of the intervention at 3, 6 and 12 months. The total number of participants reporting their impressions

varied at different time points. At 3 months 250 out of 261 (96%) intervention group participants felt confident completing the exercise at home. At 6 months, 218 out of 237 (92%) intervention group participants stated that they intended to continue to do the exercises. At 12 months, the mean rating of perceived program benefit for the intervention group was 7.8 out of 10 (SD 2.2). Most participants (n = 184/228, 81%) intended to continue to do the exercises, and 218 out of 234 (93%) would recommend the program to other people aged 65 years and older.

At 12 months intervention group participants reported on features they liked about the BEST at Home – lower limb program. The most commonly reported positive features were that the exercises could be done anytime (n = 228/230, 99%), the exercises could be done at home (n = 221/230, 96%) and that the exercises were simple to follow (n = 217/230, 94%). At 12 months, 137 out of 236 (58%) intervention group participants reported that they had problems completing the exercises on a regular basis, with the most common reasons being: going away on holiday (n = 50/236, 21%), injury (n = 43/236, 18%), lack of motivation (n = 40/236, 17%), too busy (n = 39/236, 17%), family commitments (n = 36/236, 15%) and ill health (n = 32/236, 14%).

Adverse events

One control group participant reported an adverse event associated with the exercise program, which required them to cease the program. Twenty-three participants (11 intervention, 12 control group) reported minor musculoskeletal pains, which were resolved after a short period of time. No fractures occurred while participants were performing the exercises.

Discussion

Our study did not detect any difference in fall rate between the intervention and control groups. However, it was found that a home-based exercise program for the lower limb can significantly reduce the fear of falling at 3, 6 and 12 months. Gait speed was also significantly faster in the intervention group compared to the control at 3 months. There were no significant differences in physical activity (accelerometer and self-report), quality of life, SPPB, sit to stand, balance, alternate step test, leg strength and gait speed at 6 months.

It is uncertain why there was no clear impact of the exercise intervention on the rate of falls. The exercise program instruction was provided at weeks 1, 4 and 12, and while participants were given suggestions on how to progress the exercise challenge, the exercises were not formally progressed beyond the 12 week time point. This may have resulted in a limited challenge to balance and strength over the 12 month follow-up period. On average participants in the intervention group completed the exercises less than twice per week over the 12 month period, which may not have been a high enough dose of exercise to prevent falls [39]. The intervention group performed the same exercises as the Otago Exercise Programme, which has previously been shown to reduce falls, but the BEST at Home exercise program was delivered in a group-based format and had fewer supervised sessions with the physiotherapist. The original delivery of the Otago Exercise Programme [13, 17] involved more supervision over a 12 month period, with five individual home visits (weeks 1, 2, 4, 8, 26) plus telephone contact when there were no home visits (months 3, 4, 5, 7–12) over a 12 month period. The lower amount of supervision, and particularly individual supervision, offered by the group-based exercise instruction in this study may have resulted in balance and strength challenges which were insufficient to prevent falls. Teaching home exercise in an individual's home may also be easier as it affords the opportunity to demonstrate where to safely do the exercises, which may lead to increased confidence and therefore more challenging exercise. The original Otago Exercise Programme was also most effective in people aged 80 years and over [40], an older group than the participants in the current study. The Otago Exercise Programme also reported a higher proportion of participants having had a fall at baseline, with 36–56% of participants reporting a fall in the previous 12 months [13, 17, 41], compared to our study with 27% of participants reporting having had a fall in the previous 12 months at baseline. However sub-group analysis suggested greater intervention effects in reducing the rate of falls in those who had fallen in the year prior to baseline assessment than those who had not fallen, and an even greater effect in those reporting two or more falls in the year prior to baseline, although these results did not reach statistical significance.

The significant reduction in fear of falling is an important finding of this study. Fear of falling can lead to restriction of daily activities and is associated with deconditioning, falls and frailty [42]. A recent study [43] found fear of falling to be significantly associated with falls, and a useful index in detecting falls risk in community-dwelling people aged 65 years and over, independent of physical performance. Our results support the findings of a Cochrane Review that found that fear of falling is reduced immediately after an exercise program [44].

The significant difference in gait speed at 3 months is also an encouraging finding, as slow gait speed in older adults has been identified as a risk factor for falls [45]. The improvement in gait speed was not maintained beyond 3 months, perhaps reinforcing the need for

greater supervision and/or booster sessions to ensure exercises are appropriately progressed throughout the program to maintain the effects.

The high level of acceptability of the intervention suggests that it is possible to teach people aged 65 years and over to undertake a home-based exercise program with the instruction provided in a group setting. Most participants reported that the exercises were simple to follow and they liked being able to complete them at home at their convenience. However, there was a high proportion of participants reporting barriers to completing the exercises on a regular basis. These barriers included going away on holiday, injuries, lack of motivation, being too busy, having family commitments and ill health. These factors are commonly reported in other studies [46–48] and could be addressed via targeted behaviour change techniques in future projects.

This study had many strengths. It had a pragmatic RCT design, with broad inclusion criteria. It followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines [20] and the protocol was registered prospectively and published [19]. It also attempted to minimise the risk of bias through concealed random allocation to groups, and assessor-blinded outcome assessment. The data for the primary outcome of falls was self-reported by participants, however the person following up primary outcome data with participants was blinded to group allocation and the data was dealt with in a blinded manner. There was a high level of acceptability of the program, with many participants (81% of respondents) indicating that they intended to continue the exercises and 93% would recommend the program to other people aged 65 years and older.

Limitations of the study include a sub-optimal level of adherence to the program that may have precluded participants from reaching the recommended 'dose' of balance and strength training required to prevent falls [9, 39, 5]. The participants were a fit and healthy cohort, who self-selected in response to advertisements. The participants appeared to be more active at baseline than the general older population [49] and therefore, the exercises may not have been challenging enough. The exercises were instructed in a group setting, over three sessions at weeks 1, 4 and 12, and there may not have been enough instruction sessions later in the program to allow the exercises to be progressed sufficiently. Attendance at the instruction sessions decreased later in the program and this may have reduced the intensity of balance and strength challenge with which participants were carrying out the exercises, as the later workshops taught participants how to progress the exercises to increase this challenge.

The findings suggest that further research is warranted to establish whether this model of community-based exercise delivery can be enhanced with additional exercise instruction sessions, to provide a greater intensity of challenge to balance and other reminders to promote adherence such as supportive phone calls, text messages, online videos and mobile device apps. There is also a need to investigate targeting of the intervention to participants who would benefit most from an exercise program, such as those with low initial levels of physical activity, poor strength and balance, older age and identified to be at a greater risk of falls. Exercise programs, delivered in a variety of ways, should continue to be offered in the community to assist people meet the recommendations of exercise to prevent falls.

Abbreviations

BEST: Balance Exercise Strength Training; BMI: Body mass index; CI: Confidence interval; FES-I: Falls Efficacy Scale-International; IPEQ: Incidental and Planned Exercise Questionnaire; IRR: Incidence rate ratio; MVPA: Moderate vigorous physical activity; NSW: New South Wales; SD: Standard deviation; SPPB: Short Physical Performance Battery; WHO: World Health Organisation.

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Authors' contributions

All authors made substantial contributions to the conception and design of the work. AB, CC, MK, SF assisted in the data collection. AB, AT, CS, SF contributed to the data analysis, AB, AT and SF drafted the manuscript. All authors contributed to the manuscript's critical review and approved the final version.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee (HE14/279 and HREC/14/WGONG/50). Written informed consent was obtained from all participants prior to their participation in the study. This research was performed in accordance with the National Health and Medical Research Council of Australia's *National Statement on Ethical Conduct in Human Research.*

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details
[1]Health Promotion Service, Illawarra Shoalhaven Local Health District, Wollongong, NSW, Australia. [2]Illawarra Health and Medical Research Institute, Wollongong, NSW, Australia. [3]School of Health and Society, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, Wollongong, NSW, Australia. [4]Institute for Musculoskeletal Health, The University of Sydney and Sydney Local Health District, Sydney, NSW, Australia. [5]School of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia. [6]Primary Care and Community Health, Nepean Blue Mountains Local Health District, Kingswood, NSW, Australia. [7]School of Medical Sciences, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia. [8]Department of Physiotherapy, Illawarra Shoalhaven Local Health District, Wollongong, NSW, Australia.

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Publisher's Note

Chapter 5: Effectiveness of a home-based exercise program for improving upper limb function in community-dwelling older people: a pragmatic randomised controlled trial

Chapter Five is presented in the format of the journal (PLOS One) where it has been submitted – currently under review

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Authorship contribution statement

As primary supervisor and co-author of the paper “Effectiveness of a home-based exercise program for improving upper limb function in community-dwelling older people: a pragmatic randomized controlled trial”, I confirm that Amanda Macaulay (Bates) is the lead corresponding author and has made the primary contribution to this study in each of the following areas in collaboration with co-authors Sherrington C, Furber S, Gilchrist H, van den Dolder P, Ginn K, Bauman A, Kershaw M, Franco L, Chittenden C, Tiedemann A:

- Conception and design of the research
- Data collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of the content

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

Preamble to Chapter Five

This chapter describes the results of the upper limb exercise component of the randomised control trial described in Chapter Three. The trial tested an upper limb home-based exercise program designed to prevent upper limb dysfunction among adults aged 65 years and older living in the Illawarra and Shoalhaven areas of New South Wales, Australia. We hypothesised that participants in the upper limb home-based exercise program would have an improvement in upper limb function, while improving upper limb strength and range of motion compared to the control group.

Karen Ginn, Professor of Musculoskeletal Anatomy in the Faculty of Medicine & Health at the University of Sydney and a musculoskeletal physiotherapist, and Dr Paul van den Dolder, Senior Physiotherapist developed the exercise program in collaboration with the candidate. The UL program consisted of a set of eight exercises, which included arm raises, internal and external shoulder rotation, elbow flexion and extension, shoulder press, chest press and shoulder row. The program was designed to improve strength and mobility in the shoulder. The program was tested with a group of older adults and members of Health Promotion and Multicultural Health teams of the local health service to ensure it was appropriate for the intended population.

The selected outcomes of upper limb function, measured by the Disabilities of Arm Shoulder and Hand (DASH) questionnaire, shoulder strength and range of motion, are early indicators of musculoskeletal health. Impairments in these domains are associated with pain, activity limitation, altered biomechanics, and increased risk of shoulder pathology. As such, they are used as proxy measures in research. A 12-month timeframe is appropriate to detect meaningful changes in these variables, and improvements may reflect a favourable shift in the trajectory of shoulder health, which could translate to reduced dysfunction over time.

Title: Effectiveness of a home-based exercise program for improving upper limb function in community-dwelling older people: a pragmatic randomized controlled trial

Amanda Bates[1,2*], Cathie Sherrington[2,3], Susan Furber[4,5], Heidi Gilchrist[2,3], Paul van den Dolder[6], Karen Ginn[7], Adrian Bauman[2], Michelle Kershaw[1], Lisa Franco[8], Cathy Chittenden[9], Anne Tiedemann[2,3]

[1] Health Promotion Service, Illawarra Shoalhaven Local Health District, Wollongong, Australia
[2] School of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, Australia
[3] Institute for Musculoskeletal Health, The University of Sydney and Sydney Local Health District, Sydney, Australia
[4] Formerly Illawarra Shoalhaven Local Health District, Wollongong, Australia
[5] Formerly School of Health and Society, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, Wollongong, Australia
[6] Primary Care and Community Health, Nepean Blue Mountains Local Health District, Australia
[7] Faculty of Medicine and Health, The University of Sydney, Sydney, Australia
[8] Integrated Care and Priority Populations, Illawarra Shoalhaven Local Health District, Wollongong, Australia
[9] Department of Physiotherapy, Illawarra Shoalhaven Local Health District, Australia

* Corresponding author
amanda.bates@health.nsw.gov.au (AB)

Abstract

Background

Upper limb dysfunction, including shoulder pain, is a major health issue for older people. Exercise is commonly used to treat shoulder disorders. This study aimed to determine the effect of a home-based upper limb exercise program on upper limb function compared to a lower limb exercise program, among community-dwelling people aged 65 years+.

Methods

A randomized controlled trial was conducted. One group received a home-based exercise program targeting upper limb (UL) strength, mobility and function. The other group received a home-based exercise program targeting lower limb (LL) balance and strength. Both exercise programs were taught at three group-based sessions in weeks 1, 4 and 12 post-randomization. Participants were requested to complete exercises three times per week for 12 months. The primary outcome was UL function, measured with the self-report Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. Secondary outcomes included shoulder strength and range of motion (ROM), quality of life (QOL) and physical activity.

Results

617 participants were randomly assigned to UL (n=307) or LL (n=310) groups. Mean age was 73 years, (SD 6.0) and 64% were female. No clinically important or statistically significant between-group difference was detected in UL function (measured by the DASH) at 12 months (mean difference (MD) = 0.99, 95% CI -0.82 to 2.79, p=0.283, n=462). There were no significant between-group differences in shoulder ROM, most measures of strength, physical activity (device-measured and self-report), QOL and UL function at three and six months.

Conclusion

People aged 65+ can successfully learn and adhere to a home-based exercise program for the UL with instruction provided in a group setting, however this program did not improve UL strength, mobility and function. Considering the increased rates of shoulder dysfunction in older age, more research is needed to determine the optimal exercise protocols for prevention of shoulder dysfunction.

Introduction

Upper limb dysfunction, including shoulder pain and stiffness, is a major health issue for community-living people aged 65+ years (1). Shoulder pain is the third most common musculoskeletal disorder in adults (2), after back and neck pain (3). The prevalence of shoulder pain increases with age (4-6), with estimates of point prevalence of shoulder pain in adults aged 70+ years at 13-26% (7). A 2022 systematic review of the global prevalence and incidence of shoulder pain found prevalence rates ranging from 11-55% for a reference period of 12-months or more, with the annual incidence rate varying between 8-62 per 1000 person years (8). The most frequent diagnoses in people with shoulder pain are rotator-cuff tendonitis, subacromial pain syndrome, adhesive capsulitis and acromioclavicular joint disorders (9, 10). However specific diagnoses of shoulder pain are not always straightforward with no clearly defined pathology or physical signs, and may also be the result of coexistence of multiple pathologies, and have therefore been termed as non-specific shoulder pain (10-12).

Hill et al conducted a population-based survey to estimate the prevalence of shoulder pain and examine its associations with physical function, range of motion and quality of life (6). The

findings revealed that shoulder pain disproportionately affected females and older adults. Specifically, females were 40% more likely than males to report shoulder pain and/or stiffness, and the likelihood of these symptoms increased with advancing age (6). Lifestyle factors, including tobacco use, obesity and physical inactivity, were significantly associated with a higher prevalence of shoulder pain and/or stiffness. Individuals experiencing shoulder pain and/or stiffness demonstrated a greater incidence of depressive symptoms and reported lower quality of life scores (6). Age-related decline in shoulder function was also observed, suggesting potential implications for maintaining independence among older populations.

The consequences of upper limb dysfunction are myriad. Shoulder pain creates a significant burden on individuals and the community by reducing an individual's capacity to participate in work (paid and volunteer), recreational activities and activities of daily living (3, 11). Reduced shoulder flexibility also increases the risk of older adults losing social independence (13). Reduced shoulder movement by older adults significantly reduces daily physical activity, demonstrated by a significant reduction in daily steps while wearing a shoulder orthosis (14). Shoulder immobilisation also impairs balance in older people, with a study showing a significant reduction in balance ability in community-dwelling people aged 65 years and over wearing shoulder immobilisers (15). Reduced shoulder range of motion has been identified to be associated with poor lower limb function and mobility in older adults, along with poor walking endurance capacity (16). Older adults with reduced or abnormal range of motion are 2.5 to 4.5 times more likely to exhibit poor mobility, even after adjusting for age, sex, weight, height and chronic conditions (16). This information suggests that mobility limitations in older adults can be related to both upper limb and lower limb dysfunction (16).

Preventing and reducing shoulder dysfunction in older adults will have positive impacts on their independence, physical activity, mobility, balance and falls and should be a priority. This is even more imperative when considering global population ageing, which according to the World Health Organisation is occurring at a faster pace than in the past - and 1 in 6 people globally will be aged 60 years and over by 2030 (17). The significant and growing burden of shoulder pain and disability therefore also has implications for health care costs and systems into the future.

Fortunately, shoulder dysfunction can be successfully managed and treated, and exercise is a common, cost-effective method of treating shoulder disorders (3, 18) that has moderate evidence from systematic reviews supporting its efficacy (12, 19-22). A systematic review by Pieters et al stated that the evidence for exercise as the most important strategy for shoulder pain is increasing (12). Recent meta-analyses concluded that shoulder specific exercise therapy is effective in reducing chronic shoulder pain and improving function (20, 22, 23). Shoulder specific exercises were also more effective for both providing and maintaining pain relief than usual care (23). Silveira et al acknowledged that exercise therapy should be used as the first line of treatment in managing chronic shoulder pain (23).

While strengthening exercises in multiple planes of motion focusing on strength and stability of the shoulder joint are recommended (11, 20, 24, 25), a scoping review of exercise programs for managing rotator-cuff related shoulder pain found a high variability in the parameters used to prescribe exercises for shoulder pain (26). There is still work to be done to determine if there is an optimal dose and type of exercise for the treatment of shoulder pain.

Similarly, there is limited evidence for the use of upper limb exercise in people with

asymptomatic shoulders, with most of the research focused on the treatment of shoulder dysfunction rather than prevention (27). However, shoulder exercises are routinely provided as part of a general exercise program for older adults (23) and often use elastic exercise bands for resistance, as they are effective in improving strength (28). A scoping review by Kim et al of elastic band exercises to improve shoulder function, found only a limited number of studies (27). It was noted that exercise for shoulder function using elastic bands appeared to have promising results on muscle strength outcomes, however further research is needed to determine how these exercises may affect shoulder function in an older population (27). One of the goals of the present study, therefore, is to address this notable research gap regarding the preventive effects of strengthening in older adults with asymptomatic shoulders.

While individual physiotherapy exercise programs are the traditional mode of exercise delivery for people with musculoskeletal conditions, group-based exercise programs have been found to be as effective as individual physiotherapy exercise programs (29). A recent study found that group-based exercise, individually supervised exercise and home-based exercise had similar beneficial effects in people with subacromial pain (30), however the home exercise intervention was shown to be the most cost effective (30). Granviken and Vasseljen also found similar effects of unsupervised home exercise and supervised exercise on pain and disability for people with subacromial pain when working at the same training dose (31). Recent systematic reviews and meta-analyses found that home-based exercise alone may be equally effective as other conservative treatments for non-specific shoulder pain (10, 22, 24), and supervised and unsupervised training (or self-training with one-time instruction) were equally effective on pain and shoulder function (22).

A further consideration related to exercise delivery mode for older people is their varying life

circumstances, making a choice of options important (32). Home-based exercise options may be preferable to older people for reasons of accessibility, lower cost and greater convenience, particularly for those who are unable to leave home (33, 34). This accessibility is particularly important for older adults with mobility limitations, caregiving responsibilities, or those living in regional areas. Home-based exercise programs reduce costs associated with attending sessions and transportation to get to programs (35, 36).

The study presented here sits within a larger trial that tested the effects of two different exercise programs in people aged 65 years and over. The results of the lower limb exercise program for falls have been published elsewhere (37). Building on what is already known about shoulder dysfunction, older people and exercise preferences, the primary aim of the current study was to determine the effect of a home-based exercise program on upper limb function among community-dwelling people aged 65 years and over. Secondary outcomes included shoulder strength and range of motion, quality of life and physical activity.

Materials and methods

Study design

A pragmatic randomized controlled trial (RCT) was implemented with two parallel intervention groups. Following baseline assessments, participants were randomly allocated to either the upper limb (UL) intervention or lower limb (LL) control group. The allocation sequence was generated via a computer-based randomization schedule within REDCap, prepared by a researcher who was not involved in participant enrolment. To minimize the risk of contamination, individuals residing in the same household were considered a single unit and assigned to the same intervention group. Given the nature of the exercise interventions,

blinding of participants and program facilitators to group assignment was not feasible. However, both primary and secondary outcome data were collected by assessors who were blinded to group allocation, and participants were told to not disclose their assigned exercise group to the assessors. The University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee (HE14/279 and HREC/14/WGONG/50) approved the study. All participants gave written informed consent prior to commencement of data collection. Recruitment occurred between September 2015 and May 2017. Follow-up data collection was completed in May 2018. A comprehensive protocol detailing the study's design and methodology has been published (38). The study reporting is in accordance with the Consolidated Standards of Reporting (CONSORT) (39). The trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12615000865516) on 19/08/2015, prior to commencement.

Participants

The study sample comprised community-dwelling individuals aged 65 years and older residing in the Illawarra and Shoalhaven areas, New South Wales, Australia. Recruitment strategies included paid newspaper advertisements, media releases, radio interviews, distribution of printed promotional materials and information sessions delivered to local community groups. Eligibility screening was conducted via telephone interviews. Individuals were excluded if they met any of the following criteria: cognitive impairment (defined by a score below 5 on the Memory Impairment Screen) (40); unable to walk 10 metres even with the aid of a walking device; insufficient English language proficiency to comprehend program content; diagnosis of a progressive neurological condition; recent fracture or joint replacement within the preceding six months; presence of a medical condition contraindicating physical

activity; unable to obtain clearance to exercise from their General Practitioner; or current engagement in a comparable UL or LL exercise program at a frequency of two or more sessions per week.

Intervention

The intervention group participants undertook an UL exercise program (BEST at Home – upper limb). The UL exercise program was developed by the research team to improve upper limb strength, mobility, and function. The UL program consisted of a set of eight exercises, which included arm raises, internal and external shoulder rotation, elbow flexion and extension, shoulder press, chest press and shoulder row. Participants received a set of dumbbell weights (ranging from 600g – 3kg) and an elastic resistance band, available in four levels (light, medium, heavy and extra heavy resistance). The initial exercise load was prescribed by the supervising physiotherapist during the first session. A printed manual outlining the home exercise program, including visual illustrations and detailed instructions for each exercise, was also provided. Participants were instructed to complete 10 repetitions of each exercise, three times per week, in their home setting. All exercises in the UL program were performed while seated. The intervention is outlined using the TIDieR checklist in Table 1 (41). Participants were taught strategies to progressively increase the difficulty of the exercises as they advanced through the program.

Table 1. Intervention description using the Template for Intervention Description and Replication (TIDieR) checklist

Checklist item	
1. Brief name	Balance Exercise Strength Training (BEST) at Home (upper limb) trial
2. Why	Upper limb dysfunction, including shoulder pain is a major health issue for older people. Shoulder pain is the third most common musculoskeletal disorder in adults and the prevalence increases with age.
3. What materials	Participants in the upper limb group received: - an exercise program designed to improve upper limb function (including exercise instruction, printed manual, weights and exercise band) Participants in the lower limb group received: - an exercise program designed to reduce falls and improve balance and strength in the lower limbs (including exercise instruction, printed manual and weights) - a brochure on fall prevention titled 'Staying active and on your feet'
4. What procedures	Both intervention groups attended three group-based exercise instruction sessions and three measurement sessions.
5. Who provided	Physiotherapists facilitated the exercise instruction sessions.
6. How	The exercise instruction was provided in person in small groups of approximately 10 participants.
7. Where	In the Illawarra and Shoalhaven regions, New South Wales, Australia.
8. When and how much	Exercise instruction sessions were facilitated in weeks 1, 4 and 12. Each session was one hour duration. Participants were asked to perform the exercises three times per week for 12 months.
9. Tailoring	The exercises were individualized by the physiotherapist for each participant, based on their level of ability and need.
10. Modifications	No modifications were made.
11. How well (planned)	Adherence to the exercise program was determined by self-reported exercise sessions, which were marked on postal calendars (and returned monthly)
12. How well (actual)	Participants were instructed to complete the exercises 3 times per week. Participants in the upper limb group completed an average of 104 sessions over the 12-month period (twice per week). Participants in the lower limb group completed an average of 94 sessions over the 12-month period (less than twice per week).

Participants assigned to the LL group engaged in a home-based exercise program designed to reduce fall risk by improving balance and lower limb strength. The program was based on the Otago Exercise Programme (42, 43) and comprised of 17 balance and strength exercises. Participants were instructed to complete the exercises at home three times per week (37, 38). The intervention was informed by principles of social cognitive theory (44).

Both the UL and LL exercise interventions were facilitated by two experienced physiotherapists through a series of three group-based workshops. These sessions were held in community venues such as local community centres or clubs, with each group consisting of

approximately 10 participants. Workshops were conducted at weeks 1, 4 and 12, each lasting one hour. The exercise programs were individualized to match each participant's level of ability. During each session, exercises were reviewed, techniques refined, and modifications or progressions were made by the physiotherapist based on the participant's performance and needs.

Outcome measures

Primary outcome

The primary outcome for the assessment of the UL intervention was upper limb function measured with the Disability of the Arm, Shoulder and Hand (DASH) questionnaire at 12 months (45). The DASH includes 30 items, each rated on a 5-point scale to represent: the difficulty experienced in performing various physical activities that require upper extremity function (physical function, 21 items); symptoms of pain, activity-related pain, tingling, weakness, and stiffness (pain symptoms, 5 items); and impact of disability and symptoms on social activities, work, sleep, and psychological well-being (emotional and social function, 4 items) (46). Scores range from zero to 100, with zero representing no disability and 100 the most severe disability (47). The DASH has demonstrated good test-retest reliability (ICC 2,1 = 0.93) with sensitivity of 82% and specificity of 74% (48).

Secondary outcomes

There were several secondary outcomes. Shoulder strength was measured by isometric shoulder internal and external rotation force in both left and right arms using a Lafayette manual muscle tester (Model 01165). Shoulder mobility was measured by active shoulder internal and external rotation range of motion in both left and right arms using a Baseline

digital inclinometer (Model 12-1057). The assessments of shoulder strength and mobility were conducted at baseline, three months and six months by physiotherapists who were blinded to group allocation. Quality of life was assessed with the self-report Short Form Survey 12, version 2 (SF12v2) (49). Physical activity (including daily step count, counts per minute and minutes of moderate to vigorous physical activity) was measured with an Actigraph accelerometer (model wGT3x-BT) worn at the waist (50, 51). Accelerometer data were collected over a one-week period to account for day-to-day variation in physical activity levels. Acceptable wear time was defined as a minimum of four days of 10 hours or more per day. Physical activity was also measured using self-report data from the Incidental and Planned Exercise Questionnaire (52). Paper-based questionnaires were self-completed during sessions at baseline, 12 weeks and 6 months; and via postal questionnaires at 12 months post-randomisation.

Participants also answered questions at baseline about sociodemographic details, prescription medication and comorbidities. To measure program adherence, participants were asked to record the days that they completed the exercises on the calendars that were returned each month.

Data analysis

A pre-specified statistical analysis plan was followed. Linear regression models were used to assess the effect of group allocation on the continuously scored measures (upper limb function via the DASH questionnaire, shoulder internal and external rotation force and range of movement, physical activity, quality of life), after adjusting for baseline scores. For variables that were not normally distributed (DASH score, SF-12, moderate-vigorous physical activity

(MVPA), planned physical activity, total walking) change scores from baseline to follow-up were analysed. Separate linear regression analyses were performed for each time point for continuous measures. Interaction terms in the model were used to assess for differential intervention effects by age, sex (male versus female), previous falls and baseline DASH score. Statistical significance was set at $p < 0.05$. The data analyses were undertaken blinded to group allocation and used an intention-to-treat approach. Sample size calculations suggested that 576 participants would be sufficient to detect a 10% between-group difference in the DASH total score and the secondary physical outcomes, with a 15% loss to follow up (38). The sample size calculation used the nbpower user written command in Stata (Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). A sensitivity analysis was conducted for the primary outcome to account for clustering of household participants.

Results

Participants

The participant flow throughout the trial is displayed in Figure 1. Of the 953 individuals assessed for eligibility, 308 declined participation and 28 did not satisfy the inclusion criteria. A total of 617 participants (mean age 73 years, SD 6, 64% female) were randomly assigned to either the UL group (n=310) or LL group (n=307). Baseline characteristics are detailed in Table 2, with both groups being well-matched at baseline (Table 2).

Figure 1. Design and flow of participants through the trial

[a] These participants withdrew from the study but still completed the questionnaire and their data were included in the analysis.

[b] One participant who had failed to complete three-month questionnaire completed the six-month questionnaire

DASH = Disability of the Arm, Shoulder and Hand questionnaire

Table 2. Characteristics of participants at baseline (n=617)

Characteristics	Upper limb	n	Lower limb	n	Total	n
Age (years), mean (SD)	73.2 (5.8)	310	72.9 (6.2)	307	73.1 (6.0)	617
Female sex: *n (%)*	197 (64)	310	196 (64)	307	393 (64)	617
Lives alone: *n (%)*	97 (31)	310	89 (29)	307	186 (30)	617
Medical conditions (0-17)[a], mean (SD)	2.8 (2.0)	310	2.8 (1.9)	307	2.8 (1.9)	617
Arthritis: *n (%)*	181 (59)	309	173 (58)	297	354 (58)	606
Osteoporosis: *n (%)*	57 (19)	307	66 (22)	304	123 (20)	611
Diabetes: *n (%)*	32 (10)	307	26 (9)	306	58 (10)	613
Depression: *n (%)*	48 (16)	303	51 (17)	303	99 (16)	606
Total medications (n), mean (SD)	3.3 (2.7)	305	3.0 (2.6)	304	3.1 (2.7)	609
DASH outcome measure, mean (SD)	13.2 (12.1)	310	13.2 (11.9)	307	13.2 (12.0)	617
DASH score >15[b]: *n (%)*	104 (34)	310	108 (35)	307	212 (34)	617
SF12v2: physical composite score, mean (SD)	47.8 (7.4)	298	48.0 (7.7)	304	47.9 (7.6)	602
SF12v2: mental composite score, mean (SD)	53.6 (5.4)	298	53.4 (5.7)	304	53.5 (5.6)	602
Average daily step count, steps, mean (SD)	5539.6 (2394.5)	288	5725.9 (2424.6)	297	5634.2 (2409.5)	585
Self-report physical activity, hours/week[c]: mean (SD)	34.3 (19.2)	309	33.4 (19.1)	306	33.9 (19.1)	615

[a] Possible medical conditions included: arthritis, osteoporosis, asthma, chronic obstructive pulmonary disease, angina, heart disease, heart attack, neurological disease, stroke/transient ischemic attack, peripheral vascular disease, diabetes mellitus, upper gastrointestinal disease, depression, anxiety/panic disorder, visual impairment, hearing impairment, degenerative disc disease)

[b] DASH score >15 indicates some upper limb dysfunction

[c] Measured using the Incidental and Planned Exercise Questionnaire

DASH: Disabilities of the Arm, Shoulder, and Hand questionnaire

Effect of intervention

Primary outcome

No clinically important or statistically significant between-group difference was detected in UL function (as measured by the DASH questionnaire) at 12 months (mean difference = 0.99, 95% CI -0.82 to 2.79, p=0.283, n=462). A sensitivity analysis conducted to adjust for clustering of households found similar results, with no difference in UL function in the UL group compared to the LL group (mean difference = 0.99, 95% CI -0.84 to 2.82, p=0.289, n=462).

Secondary outcomes

Table 3 shows the baseline and follow-up scores for the secondary outcomes. There was a significant between-group difference in shoulder strength, favouring the LL group, for both internal rotation (mean difference = -0.58, 95% CI -1.08 to -0.09, p=0.021) and external rotation (mean difference = -0.51, 95% CI -0.95 to -0.06, p=0.026) on the left side at three months but not at six months. There were no between-group differences in shoulder range of motion, physical activity (device-measured and self-report), quality of life and UL function at 3 or 6 months.

Table 3. Intervention effects on primary and secondary outcomes

Outcome measure	Upper limb Mean (SD), *n*	Lower limb Mean (SD), *n*	Mean difference (95% CI)	*P* value
Primary outcome				
DASH score [a c]				
Baseline	13.2 (12.1) *n*=307	13.2 (11.9) *n*=307		
3 months	12.3 (12.1) *n*=247	12.5 (12.5) *n*=260	0.39 (-0.93-1.71)	0.559
6 months	13.1 (13.4) n=248	12.7 (12.8) n=236	0.11 (-1.38-1.60)	0.882
12 months	13.8 (14.9) n=234	12.4 (13.3) n=228	0.99 (-0.82-2.79)	0.283
Secondary outcomes				
Shoulder strength, internal rotation force, right, kg, mean (SD) [b]				
Baseline	10.2 (4.5) n=309	10.6 (5.0) n=307		
3 months	10.8 (4.7) n=238	11.4 (4.9) n=244	-0.28 (-0.76-0.19)	0.244
6 months	11.5 (5.0) n=212	11.3 (5.0) n=209	0.55 (-0.04-1.13)	0.069
Shoulder strength, internal rotation force, left, kg, mean (SD) [b]				
Baseline	10.0 (4.6) n=309	10.3 (4.6) n=307		
3 months	10.3 (4.6) n=239	11.1 (4.9) n=243	-0.58 (-1.08--0.09)	0.021*
6 months	11.0 (4.9) n=213	11.1 (4.9) n=207	-0.02 (-0.59-0.55)	0.950
Shoulder strength, external rotation force, right, kg, mean (SD) [b]				
Baseline	9.0 (4.4) n=309	9.4 (5.2) n=307		
3 months	9.8 (4.4) n=238	10.3 (4.7) n=244	-0.37 (-0.82-0.07)	0.102
6 months	10.7 (5.0) n=212	10.7 (5.3) n=209	0.28 (-0.36-0.91)	0.395
Shoulder strength, external rotation force, left, kg, mean (SD) [b]				
Baseline	9.4 (4.3) n=309	9.8 (4.8) n=307		
3 months	9.7 (4.2) n=239	10.7 (4.6) n=243	-0.51 (-0.95--0.06)	0.026*
6 months	10.4 (4.7) n=213	10.8 (5.0) n=207	0.12 (-0.46-0.69)	0.692
Shoulder internal rotation range of motion, right, degrees, mean (SD) [b]				
Baseline	65.1 (14.6) n=309	65.8 (14.1) n=307		
3 months	64.7 (13.6) n=238	66.8 (14.6) n=244	-1.67 (-3.75-0.41)	0.115
6 months	65.9 (14.7) n=213	66.7 (14.6) n=209	-0.50 (-2.95-1.94)	0.686
Shoulder internal rotation range of motion, left, degrees, mean (SD) [b]				
Baseline	70.1 (13.6) n=309	70.8 (13.0) n=307		
3 months	66.9 (13.6) n=239	69.2 (14.2) n=243	-1.90 (-3.98-0.18)	0.074
6 months	67.0 (14.8) n=213	68.1 (14.7) n=209	-0.51 (-3.05-2.02)	0.690
Shoulder external rotation range of motion, right, degrees, mean (SD) [b]				
Baseline	74.2 (16.8) n=309	74.0 (15.7) n=307		
3 months	74.5 (14.8) n=238	73.5 (16.0) n=244	0.44 (-1.59-2.46)	0.672
6 months	74.4 (16.4) n=213	72.7 (17.2) n=209	1.32 (-1.04-3.69)	0.272
Shoulder external rotation range of motion, left, degrees, mean (SD) [b]				
Baseline	70.6 (15.7) n=309	71.9 (16.3) n=307		
3 months	71.6 (15.0) n=239	73.5 (16.7) n=243	-1.10 (-3.14-0.93)	0.287
6 months	72.4 (15.7) n=213	72.7 (18.4) n=209	0.85 (-1.37-3.07)	0.451
SF12 physical component summary score [b c]				
Baseline	47.8 (7.4) n=298	48.0 (7.7) n=304		
3 months	48.1 (7.0) n=243	48.5 (7.6) n=257	-0.28 (-1.2-0.6)	0.534
6 months	47.7 (7.8) n=244	48.0 (8.2) n=238	0.26 (-0.8-1.3)	0.633
12 months	47.2 (8.7) n=228	48.5 (7.6) n=227	-1.1 (-2.3-0.008)	0.052
SF12 mental component summary score [b c]				
Baseline	53.6 (5.4) n=298	53.4 (5.7) n=304		
3 months	54.4 (5.3) n=243	54.1 (5.6) n=257	-0.1 (-1.1-0.8)	0.808
6 months	54.1 (5.1) n=244	54.2 (5.3) n=238	-0.7 (-1.6-0.3)	0.185
12 months	54.2 (4.8) n=228	54.4 (5.0) n=227	-0.1 (-1.1-0.8)	0.824
Physical activity, accelerometer (counts per minute) [b]				
Baseline	230 (103) n=288	239 (111) n=297		
6 months	238 (113) n=236	246 (111) n=230	0.4 (-14.1-14.8)	0.960
12 months	246 (119) n=193	249 (111) n=205	3.2 (-10.7-17.0)	0.653
Daily steps *(n)* [b]				
Baseline	5540 (2394) n=288	5726 (2425) n=297		
6 months	5689 (2337) n=236	5957 (2653) n=231	-105 (-429-219)	0.525
12 months	5916 (2638) n=193	5958 (2532) n=205	90 (-223-402)	0.572

Outcome measure	Upper limb Mean (SD), *n*	Lower limb Mean (SD), *n*	Mean difference (95% CI)	*P* value
Moderate-vigorous physical activity, minutes/day, mean (SD) [b c]				
Baseline	17.2 (16.8) n=288	18.9 (17.4) n=297		
6 months	17.6 (17.1) n=236	20.0 (18.1) n=231	-0.4 (-3.1-2.3)	0.775
12 months	19.0 (18.6) n=193	19.8 (18.0) n=205	0.3 (-2.1-2.8)	0.785
IPEQ, total physical activity, hours per week, mean (SD) [b]				
Baseline	34.3 (19.2) n=309	33.4 (19.1) n=306		
3 months	33.1 (18.1) n=247	33.4 (19.4) n=260	-1.1 (-3.6-1.5)	0.412
6 months	33.0 (17.6) n=250	31.7 (17.3) n=244	0.9 (-1.7-3.5)	0.494
12 months	32.5 (17.6) n=235	31.3 (16.7) n=229	0.9 (-1.7-3.6)	0.491
Planned physical activity (excluding walking), hours per week, mean (SD) [b c]				
Baseline	2.2 (3.4) n=310	2.3 (3.8) n=307		
3 months	2.7 (3.1) n=251	2.8 (3.8) n=262	-0.2 (-0.8-0.5)	0.575
6 months	2.4 (2.9) n=250	2.7 (3.6) n=244	-0.04 (-0.7-0.6)	0.895
12 months	2.1 (3.5) n=237	2.1 (3.1) n=234	0.2 (-0.4-0.9)	0.514
Total walking, hours per week, mean (SD) [b c]				
Baseline	4.6 (4.8) n=310	4.7 (5.6) n=307		
3 months	5.0 (4.7) n=249	5.3 (6.7) n=261	-0.2 (-1.2-0.8)	0.702
6 months	4.8 (5.1) n=250	4.5 (4.2) n=242	0.4 (-0.5-1.3)	0.350
12 months	5.0 (6.1) n=237	5.1 (5.6) n=234	-0.03 (-1.1-1.0)	0.951
Incidental physical activity (including walking), hours per week, mean (SD) [b]				
Baseline	29.3 (17.7) n=309	28.4 (18.2) n=306		
3 months	27.4 (16.6) n=246	27.7 (17.4) n=261	-0.8 (-3.1-1.6)	0.519
6 months	28.2 (16.9) n=246	26.2 (16.6) n=243	1.5 (-1.0-4.0)	0.245
12 months	27.3 (16.2) n=235	25.9 (16.0) n=229	0.87 (-1.6-3.3)	0.487

[a] Lower scores reflect better performance
[b] Higher scores reflect better performance
[c] Skewed distribution
* Significant outcome
DASH: Disabilities of the Arm, Shoulder, and Hand questionnaire
IPEQ: Incidental and Planned Exercise Questionnaire

Sub-group analyses for the primary outcome

In planned sub-group analyses, no statistically significant differences in the intervention's effect on the primary outcome of UL function by age (*p* for interaction=0.933), sex (male versus female, *p*=0.262), or upper limb dysfunction at entry to the trial, determined by a DASH score >15 at baseline (*p*=0.932) (53) were observed. Intervention effectiveness varied significantly in people who had and had not fallen in the 12 months prior to baseline (*p*=0.027). For the subgroup of participants who had fallen in the past 12 months, the UL group displayed better UL function (lower DASH scores, mean 15.6, SD 14.8), than the LL group (DASH mean 19.1, SD 14.9) (p=0.201) at 12 months. However, for participants who had not fallen in the 12 months prior to baseline, the LL group displayed better UL function (DASH mean 10.2, SD 12) compared to the UL group (mean 13.2, SD 15) (p=0.035).

Adherence with the program

Attendance at the group-based exercise instruction sessions was documented. In the UL group, 298 (96%) participants were present at the week 1 session, 260 (84%) and 241 (78%) were present at weeks 4 and 12 respectively. In the LL group, 294 (96%) participants were present at the week 1 session, 260 (85%) and 242 (79%) were present at weeks 4 and 12 respectively. A total of 280 participants (90%) in the UL group and 279 participants (91%) in the LL group attended at least two of the three exercise instruction sessions.

Participants in the UL group reported performing the exercises twice per week, averaging 104 exercise sessions (SD 69, median 117, range 0-371) over the 12-month intervention period. In contrast, participants in the LL group reported exercising less than twice per week, with a mean of 94 exercise sessions (SD 63, median 97, range 0-287). On average, participants submitted calendar data for 10 months, and 424 participants (69%) returned completed calendars for all 12 months.

One participant in the UL group experienced a minor adverse event when an exercise band broke, requiring them to discontinue the program and seek medical attention. Additionally, 23 participants (12 UL intervention group, 11 LL control group) reported minor musculoskeletal discomfort, all of which resolved within a short duration.

Acceptability of the intervention

Participants perceptions of the intervention were assessed through surveys administered at 3, 6 and 12 months. Response rates differed across assessment periods. Confidence in

completing the home-based exercises was reported by 98% of participants in the upper limb group (239/245) at 3 months. At 6 months, 95% (236/248) of UL group participants expressed their intent to continue the exercise program. The 12-month assessment yielded a mean perceived benefit rating of 7.5 out of 10 (SD 2.1) for the UL group. At this timepoint, 81% of participants (190/235) planned to continue the exercises, and 92% (217/236) stated they would recommend the program to peers aged 65 years or older.

Intervention group participants reported their preferred aspects of the program at 12 months. The highest rated features were the ability to exercise at home (95%, n=222/234), the simple nature of the exercises (94%, n=221/234) and the flexibility to perform the exercises at any time (93%, n=218/234). Despite these positive features, nearly half (46%, 109/237) UL group participants experienced challenges with regular exercise completion. The most frequently reported barriers included injury (17%, n=40/237), family obligations (15%, n=36/237), lack of motivation (15%, n=36/237), travel (14%, n=32/237), time constraints (11%, n=26/237), and health issues (11%, n=25/237).

Discussion

Our study found that a home-based exercise program was not effective at improving upper limb strength, mobility and function in community-dwelling people aged 65 years and over. There was no difference in the primary outcome of the DASH score measured at 12 months post-randomisation between the UL and LL groups. There were no significant between-group differences in shoulder range of motion, most measures of shoulder rotation strength, physical activity, quality of life and UL function at three and six months.

Given that exercises used in the UL intervention group are commonly prescribed and used in other studies to improve shoulder function and reduce pain in adults (18, 20, 54) it was somewhat surprising to find these exercises were not effective in improving shoulder function, strength or ROM, in community-dwelling people aged 65 years and over in this study, when compared to a control group. There are several possibilities for these findings.

Firstly, there was a low level of supervision and supervised exercise progression in this study, with only three sessions of exercise instruction in the first three months of the 12-month intervention period. While participants were given suggestions on how to progress the exercises (e.g. heavier weights, more repetitions and increasing exercise complexity), supervised exercise progression beyond this time was not offered. This may have provided insufficient challenge to strength throughout the 12-month follow-up. Intervention group participants completed the exercises on average twice weekly over the 12-month period, potentially representing an inadequate exercise dose to improve upper limb function and strength. In addition to unsupervised exercise providing insufficient challenge or motivation, it is also possible that incorrect performance of the exercises did not have the desired effect. When participating in group classes, posture and position can be regularly checked and feedback provided, which may also influence outcomes (55).

Secondly, unlike previous studies (30, 31) participants in this study were not recruited specifically because of any pre-existing upper limb dysfunction or pain. Motivation may have been lower in those without upper limb dysfunction, as they may not have prioritised the need for such an exercise program. Indeed, some participants expressed a preference for the LL exercise program which had a focus on exercises to prevent falls, and this may have altered their motivation to continue with the UL exercises. This was not, however, reflected in their

adherence to the program when compared with the LL intervention, which was roughly the same.

A significant improvement in the LL group compared with the UL group was found for shoulder internal and external rotation strength on the left side, at three months. This unexpected finding may have been due to the LL group steadying themselves with the left arm while performing the LL exercises. This improvement identified only at the 3-month time point, could indicate that participants in the LL group were holding on to stabilise themselves during the balance exercises. Participants in the LL group were encouraged to reduce their support (holding on) during the balance exercises as a progression and therefore may not have been holding for support as their balance and confidence improved throughout the later part of the program.

The intervention's strong acceptability indicates that adults aged 65 and over can successfully learn to perform a home-based exercise program through group-based instruction. The majority of participants found the UL exercises easy to follow and appreciated the flexibility of completing them at home according to their own schedule. Even though our program did not have the social support that group-based programs offer, participants had more control over when the exercises were completed, which has been identified as a facilitator to physical activity and program participation (56, 57).

Despite this, almost half of the participants identified obstacles to consistent exercise completion. These included injury, family obligations, lack of motivation, travel, being too busy and health issues. Such barriers are frequently documented in existing literature (56, 57) and could be mitigated through targeted behavior change strategies (such as supportive phone

calls, text messages, online videos, peer meetings and mobile device apps) in future interventions if the goal was to increase the frequency of exercise program completion.

This study possessed numerous strengths. It employed a pragmatic RCT design, with inclusive eligibility criteria. It adhered to Consolidated Standards of Reporting Trials (CONSORT) guidelines (39) and had a prospectively registered and published protocol (38). Bias mitigation strategies included concealed randomization blinded outcome assessment. Although the data for the primary outcome of upper limb function was participant-reported using the DASH questionnaire, the staff member collecting this information remained blinded to group allocation, and all data handling was conducted in a blinded fashion. The data for the secondary outcomes were measured by trained health professionals and validated tools were used to assess physical activity and quality of life. The program demonstrated strong acceptability, with 81% of respondents expressing intent to continue the exercises and 93% would recommend it to peers aged 65+.

Limitations

The study had several limitations. Suboptimal program adherence may have prevented participants from achieving the recommended strength training dose, with participants on average completing the exercises twice per week. There may not have been enough instruction sessions later in the program to allow the exercises to be progressed sufficiently. Declining attendance at later instruction sessions may have further compromised exercise intensity, as these workshops specifically taught participants how to advance the exercises and increase difficulty. The cohort consisted of reasonably fit and healthy older adults who voluntarily responded to advertising. Participants were not recruited with a focus on pre-

existing upper limb pain or dysfunction, and therefore some of the exercises may not have been challenging enough and it is possible that there wasn't much improvement to gain from their baseline DASH score. This low level of UL dysfunction at entry to the study may have been a limitation to detecting an improvement in UL function and change may have been detected if a more sensitive, high level UL strength test (e.g. 1RM) was the primary outcome measure.

Conclusion

These findings indicate that additional research is needed to determine whether this type of home exercise program could be beneficial to older adults in general, or if it would provide more benefit to people with pre-existing UL dysfunction. A recommendation for future research is to investigate combining an UL program with a LL program for a more comprehensive home-based exercise program to improve overall strength and functional independence in people 65+ while meeting the need for people who cannot access exercise programs or prefer to exercise in their own home environment. Considering the increased rates of shoulder dysfunction in older age groups, and the emerging evidence of the impact of shoulder dysfunction on mobility limitations among older adults (16), more research is needed to determine the optimal exercise protocols for prevention of shoulder dysfunction in healthy older adults.

Author contributions

Conceptualization: A Bates, C Sherrington, S Furber, P van den Dolder, K Ginn, A Bauman, M Kershaw, A Tiedemann

Methodology: A Bates, C Sherrington, S Furber, P van den Dolder, K Ginn, A Bauman, M

Kershaw, A Tiedemann

Formal analysis: A Bates, C Sherrington, A Tiedemann

Investigation: A Bates, S Furber, M Kershaw, C Chittenden

Resources: A Bates, S Furber, K Ginn, M Kershaw, L Franco, C Chittenden

Writing - original draft: A Bates, S Furber, A Tiedemann

Writing - review and editing: A Bates, C Sherrington, S Furber, H Gilchrist, P van den Dolder, K Ginn, A Bauman, M Kershaw, L Franco, C Chittenden, A Tiedemann

Supervision: A Bates, C Sherrington, S Furber, H Gilchrist, A Tiedemann

Project administration: A Bates, C Sherrington, S Furber, L Franco, C Chittenden, A Tiedemann

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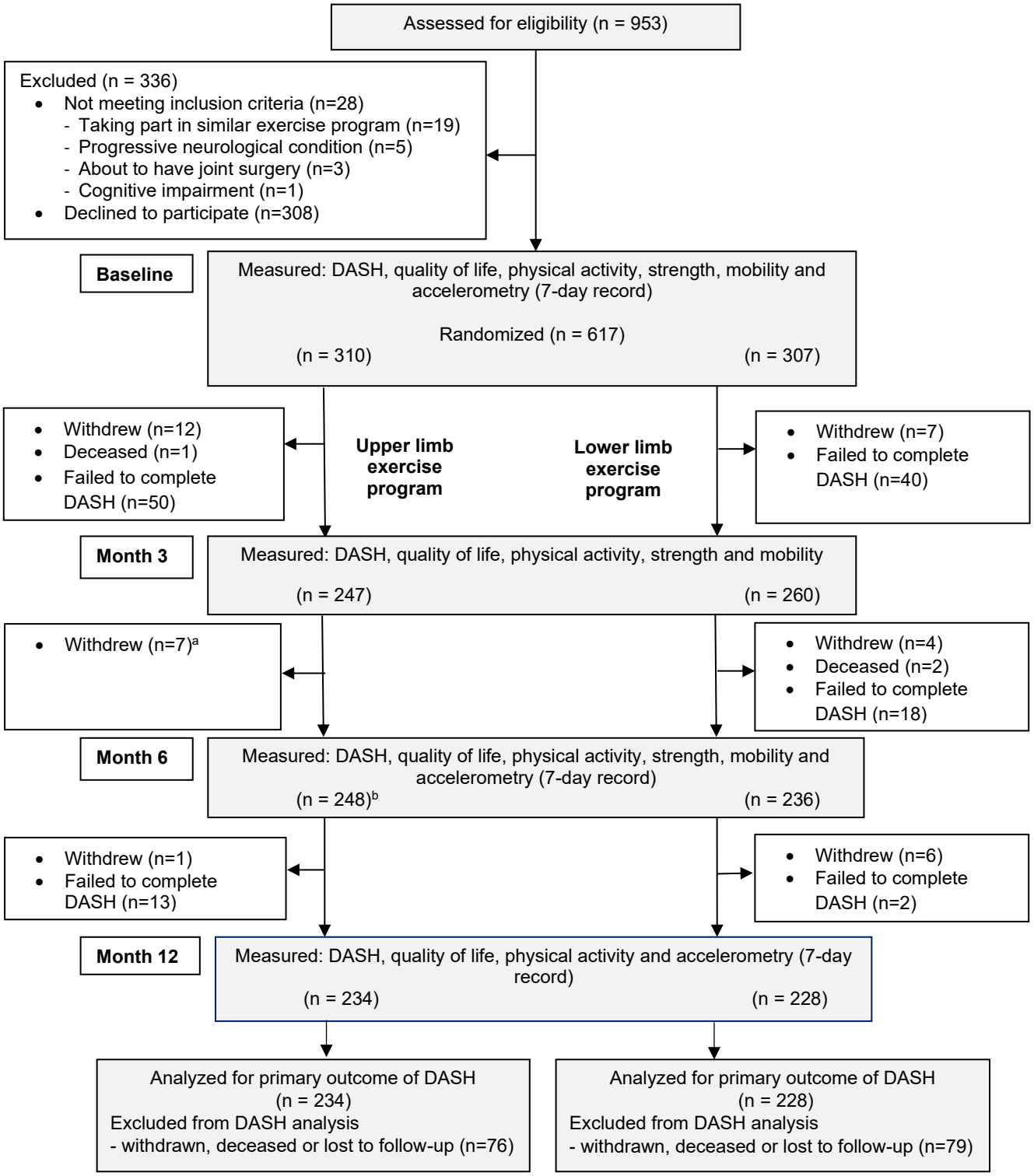

Figure 1. Design and flow of participants through the trial

[a] These participants withdrew from the study but still completed the questionnaire and their data were included in the analysis.

[b] One participant who had failed to complete three-month questionnaire completed the six-month questionnaire

DASH = Disability of the Arm, Shoulder and Hand questionnaire

Chapter 6: Reducing fall risk in older adults with COPD: pilot study to test the efficacy of a home-based exercise program with virtual care support

Chapter Six is presented in the format of the journal where it was published

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Authorship contribution statement

As primary supervisor and co-author of the paper “Reducing fall risk in older adults with COPD: pilot study to test the efficacy of a home-based exercise program with virtual care support”, I confirm that Amanda Macaulay (Bates) is the lead corresponding author and has made the primary contribution to this study in each of the following areas in collaboration with co-authors Furber S, Gilchrist H, Sherrington C, Jones N, Kershaw M, Franco L, Muir K, Tiedemann A:

- Conception and design of the research
- Data collection
- Data analysis and interpretation of findings
- Writing of the manuscript and critical appraisal of the content

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

Preamble to Chapter Six

This chapter describes the results of the pilot home-based fall prevention exercise program for patients with COPD accessing a virtual care service in Illawarra area of New South Wales, Australia. The pilot study aimed to determine the effects of the BEST at Home program on balance, strength and fear of falling in people with COPD who were enrolled in a virtual care program, and to understand the acceptability and feasibility of incorporating a home-based balance and strength exercise program (BEST at Home) into a virtual care program for people with COPD. The exercise program was based on the Otago Exercise Program and instruction was provided via small group-based workshops.

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ORIGINAL RESEARCH

Reducing Fall Risk in Older Adults with COPD: Pilot Study to Test the Efficacy of a Home-Based Exercise Program with Virtual Care Support

Amanda Bates[1,2], Susan Furber[1,3], Heidi Gilchrist[2,4], Catherine Sherrington[2,4], Nicola R Jones[5], Michelle Kershaw[1], Lisa Franco[6], Kristi-Lee Muir[7], Anne Tiedemann[2,4]

[1]Health Promotion Service, Illawarra Shoalhaven Local Health District, Wollongong, New South Wales, Australia; [2]School of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, New South Wales, Australia; [3]School of Health and Society, Faculty of the Arts, Social Sciences and Humanities, University of Wollongong, Wollongong, New South Wales, Australia; [4]Institute for Musculoskeletal Health, The University of Sydney and Sydney Local Health District, Sydney, New South Wales, Australia; [5]SydneyMSK Research Flagship Centre, Faculty of Medicine and Health. The University of Sydney, Sydney, NSW, Australia; [6]Integrated Care and Priority Populations, Illawarra Shoalhaven Local Health District, Wollongong, New South Wales, Australia; [7]Department of Physiotherapy, Illawarra Shoalhaven Local Health District, Wollongong, New South Wales, Australia

Correspondence: Amanda Bates, Health Promotion Service, Illawarra Shoalhaven Local Health District, Locked Bag 9, Wollongong, 2500, New South Wales, Australia, Tel +61 2 4221 6786, Email amanda.bates@health.nsw.gov.au

Purpose: Older adults with chronic obstructive pulmonary disease (COPD) have a higher risk of falls than their peers without COPD. Home-based exercise programs can improve balance and strength and reduce falls in older adults and could be an option for older adults with COPD who access virtual care. We pilot tested a 6-month home-based balance and strength exercise program with virtual care support aimed at improving strength and balance in people with COPD aged 50 years and over.

Patients and Methods: Adults aged 50 years and over with COPD who access a virtual care service were invited to participate in an exercise program designed to improve balance and strength and reduce fall risk.

Results: Thirteen people enrolled in the pilot program (mean age 72 ± SD 7 years, 9 females). Six participants (46%) reported having one or more falls in the 12-months prior to the study. A mixed model for repeated measures and Bonferroni correction for post hoc pairwise comparisons showed significant improvement in the Short Physical Performance Battery (SPPB) score between baseline and 6-months, effect size of 2.01; 95% CI [0.45–3.58], and between 3-months and 6-months, effect size of 1.65; 95% CI [0.48 to 2.81]. The alternate step test improved by more than 3 seconds between baseline and 3-months, effect size of −3.30; 95% CI [−5.94 to −0.66] and improved by 4 seconds between baseline and 6-months, effect size of −4.01; 95% CI [−7.42 to −0.61]. There was no significant difference in fear of falling between between baseline, 3 months or 6 months. The program had a high level of acceptability, with all participants intending to continue to do the exercises and 10/12 (83%) participants stating that they would recommend the program to other people with COPD. The program was feasible to implement, with 12/13 participants remaining in the program and attending exercise sessions.

Conclusion: On average, participants completed the exercises twice per week rather than the recommended 3 times per week. Despite this, the home-based exercise program improved strength and balance, as measured by the SPPB. The program was acceptable to participants and feasible to implement and has the potential to reduce the risk of falls in older people with COPD.

Keywords: accidental falls, exercise, chronic obstructive pulmonary disease, balance training, resistance training

Introduction

Chronic obstructive pulmonary disease (COPD) is the collective term for a number of lung diseases that interfere with normal breathing.[1] Symptoms include breathlessness, wheezing, coughing, fatigue and increased susceptibility to chest infections.[2] In 2019 COPD was the third most common cause of death globally.[3] It is estimated that the global prevalence of COPD is 10.3%, this is expected to rise due to ageing of the world's population in high-income countries and increasing smoking prevalence in low- and middle-income countries.[4] In Australia, COPD is the leading cause of avoidable hospital admissions.[5] Almost all people with COPD in 2022 in Australia (87%) had two or more chronic conditions.[6]

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Dyspnoea is the most common symptom of COPD.[7] People with COPD often have a sedentary lifestyle, as many avoid exercising to decrease their breathlessness, which results in reduced fitness and even more breathlessness on exertion.[2] People with COPD have an increased frequency of hospitalisations, which increase as the disease progresses, and an increased length of stay in hospital.[5] They also have an increased rate of co-morbidities, including heart problems, osteoporosis (due to steroid use), chest infections, anxiety and depression.[2] Falls and frailty are also commonly associated with COPD.[8,9] Frailty prevalence has been shown to be higher in people with COPD.[10] Frailty may also identify people with COPD who are at a higher risk of mortality[10] and frailty can reduce mobility and daily functioning, particularly with worsening disease.[11]

Falls in older people are a major health issue. A fall is defined as 'an unexpected event in which the participant comes to rest on the ground, floor or lower level'.[12] Approximately 30% of adults aged 65 years and over will fall each year.[13] The number of falls and fall-related injuries are likely to continue to increase, in part due to increases in the number of older people but also due to increasing morbidity and frailty.[14]

Older adults with COPD are at a higher risk of falls than their healthier peers, due to poorer balance, reduced muscle strength and exercise capacity.[9,15,16] A prospective cohort study has found the fall prevalence to be 40% in people with COPD.[17] COPD guidelines recommend regular physical activity, mainly cardiovascular exercise in the form of walking, but have also recently changed to include muscle strengthening exercises twice a week, as well as noting balance exercises would be beneficial.[18]

A Cochrane systematic review and meta-analysis[19] found strong evidence that exercise programs can reduce the rate of falls in older people. The most effective exercise programs are those that focus mainly on balance and strength training.[19] The World Falls Guidelines recommend exercise programs for fall prevention among older adults living in the community, and these programs should include balance-challenging and functional exercises. The programs should be conducted three times a week or more, tailored to the individual, and progressively increased in intensity over at least 12 weeks. For enhanced effectiveness, these programs should be continued beyond the initial 12-week period.[20] Home-based exercise programs can reduce falls and may be suitable for people living in the community with COPD who are unable to access face-to-face programs.[21,22] Travel to a face-to-face program can be physically demanding for people with COPD, due to breathlessness and fatigue and the need for use of supplemental oxygen.[23]

The Illawarra Shoalhaven Local Health District of New South Wales (NSW), Australia, has a Virtually enhanced Community Care (VeCC) service. VeCC is a multidisciplinary service designed to support patients to manage their health conditions while remaining in the community and reducing potentially preventable hospital admissions. VeCC provides a combination of face-to-face and virtual care services including remote monitoring and care coordination, which is particularly beneficial for patients with chronic conditions such as COPD and heart failure.

As part of the VeCC Chronic Disease Management Service, patients are equipped with devices to monitor oxygen levels, blood pressure, blood glucose levels and temperature. This remote monitoring allows clinicians to assess patients' conditions in real-time, providing timely interventions when needed. The service aims to support patients in managing their conditions effectively at home, reducing the need for hospital visits and improving overall health outcomes.

The BEST at Home exercise program was recently evaluated for its effect on falls, balance, strength and fear of falling in a randomized controlled trial (RCT) in people aged 65 years and over living in the community.[24] The exercise program was based on the Otago Exercise Programme,[21,25] but with the instruction provided in small group workshops rather than individual home visits.[26] The BEST at Home RCT was conducted in the Illawarra and Shoalhaven areas in New South Wales, Australia with a healthy community cohort and there was a significant improvement in gait speed and reduction in fear of falling in the intervention group. The BEST at Home program also had a high level of acceptability with many participants stating that they would continue the exercise program and would recommend the program to others.[24] This healthy community cohort did not demonstrate a reduction in falls; however this may have been because the participants self-selected to enroll in the trial and their baseline level of physical function was too high to show benefits in terms of fall prevention. Therefore, the BEST at Home program was adapted for people with COPD, as they are a clinical population identified to be at a higher risk of falls due to reduced exercise capacity, muscle strength and poor balance.

Our pilot study aimed:

1. to determine the effects of the BEST at Home program on balance, strength and fear of falling in people with COPD who were enrolled in a virtual care program, and
2. to understand the acceptability and feasibility of incorporating a home-based balance and strength exercise program (BEST at Home) into a virtual care program for people with COPD.

We hypothesized that participant strength and balance would increase and fear of falling would decrease after taking part in the home-based exercise program.

Materials and Methods

Study Design

The design was a six-month before and after study, and participants were provided with the BEST at Home exercise program. Participants were assessed at baseline (week 1), three months and six months. The University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee (2022/ETH01335) approved this study. The study reporting is in accordance with the Consolidated Standards of Reporting (CONSORT).[27] The trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12622001102763) on 10/08/2022 prior to commencement.

Eligibility/Recruitment/Participants

Participants were community-dwelling adults aged 50 years and over with a diagnosis of COPD who were enrolled in the Chronic Disease Management Service of VeCC in the Illawarra Shoalhaven Local Health District, no spirometry FEV1/FVC cutoffs were used. Participants in the Chronic Disease Management Service are provided with all equipment required to monitor their health, such as a pulse oximeter and tablet computer. Participants were recruited via a pop-up question on their virtual care tablet asking if they wanted to participate in a study to improve their balance and strength. If they selected yes, they were contacted by a pulmonary physiotherapist involved in the research.

Participants were screened for eligibility over the telephone. Participants were considered ineligible if they had any of the following: insufficient English language proficiency to read and comprehend program materials; a progressive neurological disease (eg Parkinson's disease, multiple sclerosis); joint replacement or fracture within the last six months; a medical condition precluding exercise (eg unstable cardiac disease, uncontrolled hypertension, uncontrolled metabolic diseases) or unable to obtain medical clearance to participate in exercise (as determined by their General Practitioner). Neurological conditions were excluded due to their higher risk of falls independent of COPD.[28]

Intervention

Participants were provided with a home-based exercise program that aimed to improve balance and strength in the lower body. The program was based on the Otago Exercise Programme[21,25] and included 13 balance and strength exercises, including tandem stand, tandem walk, sideways walking, backwards walking, hip abduction, knee extension and knee flexion, calf raises, semi squats, sit to stand, one leg stand and stair walking. Participants were instructed to perform 10–20 repetitions of the prescribed exercises at home three times per week. Participants were given ankle cuff weights (0.5kg – 3kg), with the weight determined by the physiotherapist at their first session and based on the participant's current functional ability. Participants also received an exercise manual containing diagrams and descriptions of the exercises and a copy of 'Staying Active and On Your Feet', a booklet about preventing falls.[29]

The exercise instruction was delivered face-to-face, in small group workshops at baseline and three months by a physiotherapist experienced in pulmonary rehabilitation and musculoskeletal conditions. The workshops were run in local community health centres or community venues and included approximately three participants per workshop. Exercise instruction workshops occurred at weeks 1 and 13 and were one hour in duration. Participants were advised to practice the exercises at home three times a week for 6 months. The program was tailored to each participant's level of

Table 1 Intervention Description Using the Template for Intervention Description and Replication (TIDieR) Checklist

Checklist item	
1. Brief name	Balance Exercise Strength Training (BEST) at Home (COPD)
2. Why	More than 25% of people aged 65 years and over fall at least once each year. Older adults with chronic obstructive pulmonary disease (COPD) have a higher rate of falls than healthy peers. Balance and strength training has been shown to reduce the risk of falling in older people.
3. What materials	Participants received: an exercise program designed to improve balance and strength in the lower limbs (including exercise instruction, printed manual and ankle weights), a booklet on preventing falls titled 'Staying active and on your feet'
4. What procedures	Participants received two group-based exercise instruction sessions, three video calls and three measurement sessions.
5. Who provided	Physiotherapists delivered the exercise instruction. Physiotherapists and trained research assistants conducted the measurements.
6. How	The exercise instruction was delivered face-to-face in small groups of approximately of 3 participants.
7. Where	In the community of the Illawarra and Shoalhaven regions, NSW, Australia.
8. When and how much	Exercise instruction sessions were held in weeks 1 and 13 (1 hour duration). Participants were asked to perform the exercises three times per week for 6 months. The first measurement session occurred at baseline before the participant was instructed in the exercises. The second and third measurement sessions were held at 3 months and 6 months. Video calls occurred at weeks 2, 4 and 8.
9. Tailoring	Exercises were individually tailored by the physiotherapist for each participant.
10. Modifications	No modifications were made.
11. How well (planned)	Adherence to the exercise program was assessed by self-reported exercise sessions, which were marked on calendars (and returned monthly)
12. How well (actual)	Participants were asked to perform the exercises 3 times per week. Participants completed an average of 55 sessions over the 6-month period (just over twice per week).

ability. At each workshop, the physiotherapist reviewed the exercises, corrected techniques, and adjusted or progressed the exercises based on each participant's capabilities. Participants were provided with additional ankle cuff weights as required. Participants were taught how to gradually increase the difficulty of each exercise and were encouraged to make the balance exercises more challenging as they progressed through the program (see Table 1 TIDieR checklist).

The physiotherapist conducted follow-up video calls with participants at weeks 2, 4 and 8 via the tablet provided to the participant by VeCC. During these video calls the physiotherapist checked if the participant was completing the exercises, monitored the exercise technique and asked if they were having any issues with the exercises and their COPD. The physiotherapist also answered any questions asked by the participant. Participants were also able to contact the physiotherapist if they had any questions in between their scheduled video calls.

Outcome Measures

Quantitative/Physical Measures

Outcome measures were completed at baseline, three, and six months, and included balance, strength, gait speed and fear of falling. There were two primary outcomes, lower limb function, assessed with the Short Physical Performance Battery (SPPB)[30–33] and fear of falling, assessed with the short version of the Falls Efficacy Scale-International (FES-I).[34,35]

There were several secondary outcomes. Lower limb strength and balance were assessed with the sit to stand, standing balance, four meter walk,[30] the alternate step test[36] and a knee extension (quadriceps) strength test.[37] The assessments of strength and balance were conducted by physiotherapists and trained research assistants.

Falls were self-recorded with monthly calendars for a 6-month period, commencing from their first workshop. A fall was defined as 'an unexpected event in which the participant comes to rest on the ground, floor, or lower level'.[12] Calendars were returned in reply paid, pre-addressed envelopes. If calendars were not returned, participants were telephoned and asked if they had any falls for that month. Participants who reported a fall on their calendar were telephoned to confirm the fall and obtain details about fall location, any injuries and if treatment was sought.

Qualitative/Process Measures

Questionnaires were self-completed during sessions at baseline, 3 months and 6 months. The baseline questionnaire included questions about demographic details, comorbidities, prescription medications, falls in the past 12 months, fear of falling (short FES-I), and self-rated balance perception. In order to measure program adherence, participants were asked to record on their calendars the days that they completed the exercises each month. Acceptability and feasibility were also assessed by questions at 3 months and 6 months.

Participant acceptability of the program was assessed by:

- whether participants would recommend participation in the program to other people with COPD, and
- whether participants intended to continue to do the exercises.

The feasibility of implementation was assessed by:

- the retention of participants in the program, assessed by the number of participants who withdrew consent or participation, and
- overall exercise adherence and attendance data at exercise sessions

Statistical Analysis

Baseline characteristics were summarised either by central tendency (mean) and dispersion (standard deviation) or frequency and percentage. Primary and secondary quantitative outcomes captured at baseline, 3-months and 6-months were assessed for changes over time. All outcomes were assessed for the assumption for sphericity in repeated measures analysis of variance using Mauchly's test, prior to conducting a one-way repeated measures ANOVA. In the event of a violation of this assumption and missing values, a mixed linear model for repeated measures using restricted maximum likelihood estimation was conducted for all outcomes. A first-order autoregressive within-subject residual was applied to account for within-subject correlation. The effect of time was assessed for all outcomes, where a significant time effect was apparent, a comparison of baseline with each 3- and 6-month visit, and 3-month versus 6-month was made. To adjust for post-hoc multiple comparison testing, the Bonferroni correction was applied. StataCorp. 2024. Stata Statistical Software: Release 18.5 College Station, TX: StataCorp LLC was used for all statistical analysis and the statistical significance level was at $\alpha = 0.05$.

Results

Participants

Baseline Characteristics

Recruitment occurred between during September and October 2022. A total of 96 clients from VeCC were asked via a question on their tablet if they would like to participate in a research study aiming to improve strength and balance in people with COPD. Twenty people declined participation; 41 people did not respond to the question and 1 person was discharged from the service. A total of 34 people expressed interest in the program and were screened for eligibility, 2 were excluded due to Parkinson's Disease, 1 was unable to obtain medical clearance from their GP, 18 failed to return their consent form and this was deemed as declining to participate, and 13 enrolled in the study.

The mean age was 72 years (±SD 7), 69% (9/13) were female. Six participants (46%) reported having one or more falls in the 12 months prior to the study. The baseline characteristics of participants is presented in Table 2. The flow of participants through the study is shown in Figure 1.

Table 2 Characteristics of Participants at Baseline

Characteristics	All (n=13)
Age (years), mean (SD)	72 (7)
Female: n (%)	9 (69)
Fallen in the past 12 months: n (%)	6 (46)
Self-rated balance fair/poor: n (%)	6 (46)
Self-rated fear of falling ≥ moderate: n (%)	2 (15)
Total medications (n), mean (SD)	8.1 (4)
Medical conditions (0–17)[a], mean (SD)	6.8 (3)
Arthritis: n (%)	6 (46)
Osteoporosis: n (%)	4 (31)
Depression: n (%)	6 (46)
Anxiety: n (%)	5 (39)
Diabetes: n (%)	5 (39)
Short FES-I, mean (SD)	12.7 (5)
Previously completed a Pulmonary Rehabilitation Program: n (%)	6 (46)

Notes: [a]Possible medical conditions included: arthritis, osteoporosis, asthma, chronic obstructive pulmonary disease, angina, heart disease, heart attack, neurological disease, stroke/transient ischaemic attack, peripheral vascular disease, diabetes mellitus, upper gastrointestinal disease, depression, anxiety/panic disorder, visual impairment, hearing impairment, degenerative disc disease.
Abbreviation: FES-I, Falls Efficacy Scale-International.

Quantitative/Physical Measures

The assumption of sphericity was violated for the primary outcome SPPB, and secondary outcomes: sit to stand and knee extension. The assumption held for the four-metre walk, standing balance, the alternative step test and the short FES-I. All physical measures trended in the direction of participant improvement, with significant findings for the SPPB and the alternate step test. The SPPB score increased by over 2 points from baseline to 6 months (mean difference of 2.01; 95% CI [0.45 to 3.58]) and increased by 1.65 points from 3 to 6 months (mean difference of 1.65; 95% CI [0.48 to 2.81]). The alternate step test improved by more than 3 seconds from baseline to 3 months (mean difference of −3.30; 95% CI [−5.94 to −0.66]) and improved by 4 seconds from baseline to 6 months (mean difference of −4.01; 95% CI [−7.42 to −0.61]). See Table 3. There was no evidence of a significant difference in fear of falling between between baseline, 3 months or 6 months. During the 6-month study period two falls were reported by two participants. One fall resulted in a fracture and the other fall resulted in no injury.

Adherence

All (100%) participants attended the week 1 session. Twelve participants (12/13, 92%) attended both the three-month and six-month sessions. There was a high level of adherence for the video calls that were performed at weeks 2, 4 and 8. Participants reported completing the exercise sessions just over twice per week with an average of 55 (SD 19, range 15–79) exercise sessions over the 6-month period, as determined by the exercise sessions recorded on the monthly calendars.

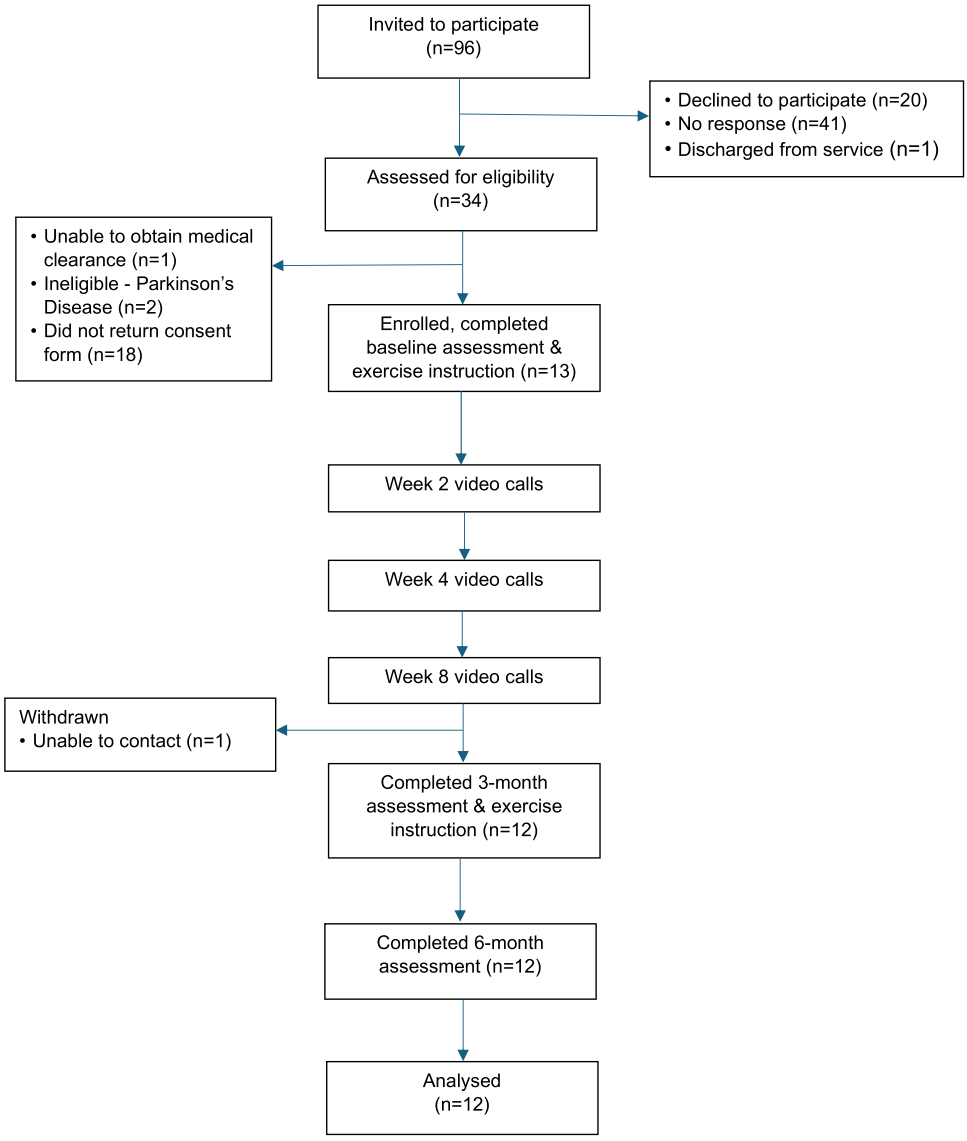

Figure 1 Design and flow of participants through the trial.

Process Measures

Acceptability Questions

Participants completed questions on their thoughts of the intervention at 3 and 6 months. Twelve participants completed the 3-month questionnaire. At 3 months, 12 out of 12 (100%) participants felt that the face-to-face exercise instruction session gave them enough information to do the exercises at home. Most participants (11/12, 92%) felt confident doing the exercises at home and felt the video calls helped with performing the exercises. Participants were asked what additional support they would have liked throughout the program. The top responses, reported by 6/12 (50%) participants were text message reminders to exercise and more information on COPD and exercise.

Twelve participants completed the 6-month questionnaire. Participants reported on features they liked about the BEST at Home – COPD program at 6 months. The most reported positive features were that the exercises could be completed at home (n=12/12, 100%), the exercises could be done anytime (n=12/12, 100%) and that the staff are helpful (n=12/12, 100%). At 6 months, 6 out of 12 (50%) participants reported that they had difficulty completing the exercises regularly, with the most common reasons being: injury (n=4/6, 67%), ill health (n=3/6, 50%) and lack of motivation (n=2/6, 33%). At 6 months, the mean rating of perceived program benefit on strength and balance was 8.1 out of 10. All participants

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Table 3 Intervention Effects of Primary and Secondary Outcomes

Variable	Baseline	3-Month	6-Month	3-Month Minus Baseline	6-Month Minus Baseline	6-Month Minus 3-Month
	Mean (SD)			Mean Difference (95% CI)^		
SPPB (0–12)[a]	8.5 (3.8) n=13	9.1 (3.2) n=12	10.6 (2.5) n=11	0.37 [−0.75 to 1.49]	2.01 [0.45 to 3.58]*	1.65 [0.48 to 2.81]*
Falls Efficacy Scale-International (7–28)[b]	12.7 (4.6) n=13	13.2 (4.4) n=12	12.5 (4.0) n=12	0.91 [−1.39 to 3.21]	0.11 [−2.88 to 3.11]	−0.79 [−3.10 to 1.51]
Sit to stand (sec)[b]	19.8 (10.8) n=13	14.1 (6.6) n=11	14.0 (8.0) n=11	−4.11 [−8.62 to 0.40]	−5.50 [−11.4 to 0.44]	−1.39 [−6.10 to 3.31]
Alternate step test (sec)[b]	13.8 (5.8) n=13	10.2 (3.7) n=12	9.7 (2.1) n=11	−3.30 [−5.94 to −0.66]*	−4.01 [−7.42 to −0.61]*	−0.71 [−3.46 to 2.04]
Gait speed, time to walk 4m (sec)[b]	4.3 (1.0) n=13	3.9 (1.8) n=12	3.7 (1.2) n=11	−0.29 [−1.03 to 0.45]	−0.59 [−1.56 to 0.37]	−0.30 [−1.07 to 0.47]
Knee extension strength, average of left and right legs, kg[a]	15.9 (8.9) n=13	16.8 (8.5) n=12	16.6 (7.1) n=11	0.85 [−3.48 to 5.19]	1.03 [−4.72 to 6.78]	0.18 [−4.33 to 4.69]
Standing balance, sum of feet together, semi-tandem, tandem times, sec, 0–30[a]	26.6 (4.7) n=13	28.4 (2.8) n=12	29.3 (2.4) n=11	1.62 [−1.18 to 4.41]	2.63 [−0.66 to 5.93]	1.02 [−1.90 to 3.93]

Notes: [a]Higher scores reflect better performance. [b]Lower scores reflect better performance. *Significant at alpha=0.05; ^Effect differences using mixed model for repeated measures.

Abbreviations: SPPB, Short Physical Performance Battery; CI, confidence interval.

(n=12/12, 100%) intended to continue performing the exercises, and 10 out of 12 (83%) would recommend the exercise program to other people with COPD.

There were no adverse events reported throughout the study.

Discussion

This pilot study found a significant improvement in lower limb function (including balance, lower limb strength and mobility) after completion of the BEST at Home exercise program. All other physical measures trended in the direction of participant improvement. There was no intervention effect on fear of falling.

Participants reported a high level of acceptability of the program, with all participants indicating that they intended to continue the exercises and 83% would recommend the exercise program to other people with COPD. All participants reported that they liked that the exercises could be completed at home, and they could be done anytime. Half of the participants reported barriers to completing the exercises on a regular basis. The most reported barriers were injury, ill health, and lack of motivation. As suggested by participants, the program could be revised to include text messages and more information on exercise and COPD. These findings show opportunities for refinement of the program.

This exercise program appears to be feasible in terms of retention of participants in the program and attendance at exercise sessions. It was encouraging to see a high retention rate, with most participants remaining in the program and attending the follow-up sessions. The overall adherence to the exercise program was lower than the 3 times per week prescribed. On average participants completed the exercise program just over twice per week for the 6 month duration of the pilot, which may not have been a high enough dose of exercise to prevent falls.[38]

One participant was lost to follow up and had reported personal family issues prior to discontinuing. Anecdotal evidence from participants was that they did not always feel well enough to exercise and some participants had extended hospital stays during the pilot. Given the high rates of comorbidity in people with COPD[6] and high rates of hospital admission,[5] it is important to maintain contact with participants to encourage them to resume exercise again at a suitable level after any break.

Qualitative research has identified unpredictable disruptions to participation in programs for people with COPD. The causes of these disruptions included illness (eg exacerbation of their COPD or worsening co-existing condition), health care appointments and other conflicting priorities.[23] Service provider flexibility to overcome these challenges are

important if people are going to continue or re-establish participation in an exercise program after an interruption. Attendance at pulmonary rehabilitation programs is relatively low,[39,40] and home exercise programs may provide greater flexibility in terms of attendance/participation for people with COPD.

Only two falls were reported during the 6-month study period, which is much lower than the 13 falls (from 6 participants) reported in the 12 months prior to the baseline questionnaire. There appeared to be fewer falls experienced during the intervention period, but this would need to be confirmed with more robust methods, including a comparison control group and longer follow-up period.

We acknowledge that there was no impact on fear of falling as measured by the short FES-I. The mean score for the short FES-I was in the moderate range (FES-I: 9–13) for all time points.[35] This is in contrast to other research that has found an increased level of fear of falling in people with COPD[41] and a significant reduction in fear of falling following a pulmonary rehabilitation program.[42] This may have been the result of our small sample size in this pilot and should be explored further.

Limitations of this pilot include having no control group in a small single group study. Given the small study size there was no power to adjust for baseline differences and account for regression to the mean (RTM). However, results from baseline to month 3 are comparable which suggests any RTM effect is small or negligible. Recruitment into the study was lower than anticipated and we did not reach our target sample size of 50 participants. Due to ethics requirements, the staff from VeCC were unable to encourage patients to participate in the study. In real-world implementation, staff would be talking to their patients about the exercises and their importance in managing their health condition/s. Participants self-selected to participate, and this may have resulted in a more motivated subset. A spike in Covid cases around the time of recruitment may have also made this population hesitant to enroll in a new program that involved some face-to-face sessions. The data for falls were self-reported by participants, however all participants who reported a fall were followed up by the research team to determine the circumstances of the fall. There was also a sub-optimal level of adherence to the program, as self-reported by participants, with participants not reaching the recommended dose of three sessions per week to prevent falls. However, due to reduced muscle strength and deconditioning in people with COPD, performing the exercises twice per week in this program was enough to show an increase in balance and strength.

This challenge in recruiting participants with COPD may be related to anxiety around breathlessness and exercise. It has been noted that patients with COPD experience worse psychological health than people with other chronic health conditions,[2] which may impact their motivation to enroll in exercise programs or research. Chronic illness and poor psychological health have been associated with lower adherence to exercise,[43] which was noted in this pilot, therefore patients may require additional encouragement and support to participate in an exercise program. Some of this additional support could be provided in the form of text message reminders and more information on exercise and COPD, as identified by participants in this program.

To avoid this apprehension of enrolling in an exercise program for COPD, a program such as this could be incorporated into standard care provided in virtual care programs for people with COPD. Participants may feel more comfortable working with staff who are already involved in their care and understand their current health status. Staff would be able to provide additional support and reassurance to patients in relation to the exercises.

Conclusion

This home-based exercise program appears to be acceptable to participants and has the potential to increase strength, balance and mobility in older people with COPD. While improvements were observed, adherence levels did not reach the recommendations for fall prevention. Adherence to the program could be addressed with additional behavior change strategies, and support and flexibility from service providers. A larger scale randomized controlled trial should be designed to confirm the present findings and provide evidence for the benefit of balance and strength training in people with COPD accessing virtual care.

Clinical Trial Registration

The trial was registered with the Australian and New Zealand Clinical Trials Registry (ACTRN12622001102763) on 10/08/2022 prior to commencement.

Data Sharing Statement

The data that support the findings of this study are available on request from the corresponding author.

Ethics Approval

The University of Wollongong and Illawarra Shoalhaven Local Health District Human Research Ethics Committee (2022/ETH01335) approved this study. All participants gave written informed consent before data collection began. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

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Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, data collection, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article. All authors reviewed the article before submission and have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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Chapter 7: Discussion and Conclusion

7.1. Authorship contribution statement

As primary supervisor, I confirm that Amanda Macaulay (Bates) authored Chapter Seven, Discussion and Conclusion. Critical feedback was provided from supervisors Professor Anne Tiedemann and Dr Heidi Gilchrist.

Professor Anne Tiedemann

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18 December 2025

Amanda Macaulay

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18 December 2025

7.2. Overview

The overall aim of this thesis was to investigate new implementation approaches for delivering home-based exercise programs for older people. The specific aims were to:

1. Summarise the current evidence for home-based exercise programs for older people **(Chapter 2)**, in relation to:
    a. preventing falls in older adults in the community
    b. reducing upper limb dysfunction, and
    c. preventing falls in people with COPD
2. Design and evaluate the effect of a home-based exercise program on falls and upper limb dysfunction in adults aged 65 years and older **(Chapters Three, Four and Five)**
3. Design and pilot test a home-based based exercise program for preventing falls in older adults with COPD **(Chapter Six)**

7.3. Principal findings

Considering the current global population growth of people aged 65 years and over,[1] interventions to promote physical activity are crucial. The provision of a wide variety of physical activity programs to suit the different preferences of older adults is essential. The WHO Guidelines on Physical Activity and Sedentary Behaviour recommend that older adults should engage in 150 minutes of moderate-intensity aerobic activity and perform muscle strengthening on at least two days per week and balance training on three or more days per week to maximise health benefits.[2] Only one in three people in Australia aged 65 years or over met the physical activity guidelines in 2022,[3] and adherence to both strength and balance recommendations has been shown to be as low as 3% in a population of older adults.[4] It has

been noted that greater provision and scale up of exercise programs for older people is urgently needed.[5]

Older adults face multiple barriers to meeting the guideline recommendations for both physical activity and fall prevention.[6,7] Home-based exercise programs may assist in addressing some of these barriers. A review of the literature presented in **Chapter Two** summarised the current evidence around the effectiveness of different types of home-based exercise programs for:

- preventing falls in older age
- preventing and reducing shoulder dysfunction in older age
- preventing falls in older people with COPD

7.3.1. Evidence for home-based exercise for preventing falls

The review found many different systematic reviews and meta-analyses that demonstrate the effectiveness of home-based exercise programs to improve physical function and prevent falls in older adults.[8-11] The review identified that adherence to exercise programs is influenced by program design and implementation support, such as phone calls and home visits. It also found that programs delivered by health professionals are associated with greater effectiveness than those delivered by non-professionals.[8] The Otago Exercise Programme, for example, was originally developed as a home-based exercise intervention delivered through multiple individual home visits by trained health professionals.[12,13] While this model has been shown to be cost-effective in reducing falls and related healthcare costs, its reliance on repeated one-to-one visits makes it relatively resource intensive to deliver, which may limit

scalability in routine practice. This highlights an important distinction between cost-effectiveness at the health system level and the practical resource requirements associated with implementation at scale.

7.3.2. Evidence for home-based exercise for preventing upper limb dysfunction

The review found evidence to support home-based exercise programs in people with pre-existing upper limb and shoulder dysfunction.[14-16] However, there was a very limited amount of evidence for home-based exercise for the prevention of upper limb dysfunction in older adults, with most of the research focused on the treatment of pre-existing upper limb/shoulder dysfunction rather than prevention,[15-17] and not specific to older adults.[14-16] Due to the scarcity of evidence surrounding exercise for the prevention of shoulder dysfunction, there is a need for more research to determine the optimal exercise protocols for the prevention of shoulder dysfunction in healthy older adults. The research described in detail in **Chapter Four** sought to address this research gap. The review also identified the emerging understanding that shoulder dysfunction is associated with mobility limitations in older adults,[18] demonstrating the broad importance of preventing upper limb dysfunction as people age.

7.3.3. Evidence for home-based exercise in preventing falls in people with COPD

The review identified that older adults with COPD have an elevated fall risk due to poor balance, reduced strength and limited exercise capacity.[19-21] Home-based pulmonary rehabilitation programs show similar outcomes to centre- or group-based programs and may be more accessible for those with mobility or respiratory limitations.[22,23] There is limited evidence surrounding home-based exercise specifically to prevent falls in older adults with

COPD,[24-26] and a clear need for more targeted, evidence-based home-based exercise programs specifically for balance and strength in older adults with COPD. A pilot trial to address this issue is reported on in **Chapter Six**.

7.3.4. Design, implementation and evaluation of home-based exercise programs for older adults

Addressing the problems of fall prevention and shoulder dysfunction among older adults require interventions that have been thoroughly tested. Drawing on the evidence described in **Chapter Two**, **Chapter Three** presented the trial protocol for a prospectively registered pragmatic randomised controlled trial of two home-based exercise programs to prevent falls and upper limb dysfunction in older adults. The trial protocol documented the methodology for testing the interventions. The protocol also included the Template for Intervention Description and Replication (TIDieR) checklist,[27] and described a rigorous design of a scalable model of home-based exercise programs that could be broadly implemented to address two major health issues in older adults – falls and upper limb dysfunction.[28-31]

As outlined in detail in **Chapters One** and **Two**, preventing falls in community-dwelling older adults is crucial because falls are a leading cause of injury, hospitalisation and loss of independence.[29] The prevention of upper limb dysfunction in older adults is also an important (albeit under-recognised) issue in older adults, with many older people experiencing upper limb dysfunction.[30,32] The association between shoulder dysfunction and mobility limitation in older adults is an emerging issue, with a reduced shoulder range of motion associated with poorer performance on lower limb function tests and walking endurance.[18] The prevention of shoulder dysfunction therefore appears to have broader implications for overall mobility and

independence in older adults. The interventions described in **Chapter Three** were designed based on these imperatives, as well as the current evidence for home-based exercise, and with reference to the social cognitive theory which describes the interaction between personal factors, behaviour and the environment.[33] Participants in the lower limb exercise group received a home-based exercise program based on the Otago Exercise Programme, focused on improving balance and strength of the lower limb. Participants in the upper limb exercise group received a home-based exercise program focused on improving upper limb strength, mobility and function, that was designed by members of the research team.

The results of the lower limb exercise component of this pragmatic randomised controlled trial are presented in **Chapter Four**. A total of 617 (mean age 73 years, 64% female) community-dwelling adults aged 65 year and over from the Illawarra and Shoalhaven regions in New South Wales, Australia participated in the trial.[34] There was no significant difference in the primary outcome of fall rates between the intervention and control group. Secondary outcomes included fear of falling, strength, balance, gait speed, physical activity and quality of life. The intervention group demonstrated significant reduction in fear of falling at 3, 6 and 12 months, and improved gait speed at 3 months compared to controls. The high level of acceptability indicated that it was possible to teach people aged 65 years and over to undertake a home-based exercise program with instruction provided in a group setting.

Limitations included a sub-optimal level of adherence to the program of less than three times per week. Improving adherence could be addressed via targeted behaviour change techniques in future projects. Participants in the study were a generally healthy cohort who self-selected in response to advertisements, and it is possible that the exercises may not have been

challenging enough for this cohort. This suggests that future interventions of a similar nature should be targeted at those with lower initial levels of physical activity, with poorer baseline levels of balance and strength, older age and identified to be at a greater risk of falls.

The results of the upper limb exercise component of this pragmatic randomised controlled trial are presented in **Chapter Five**. This randomised controlled trial (n = 617) investigated the effectiveness of a home-based upper limb exercise program compared to a lower limb exercise program in improving shoulder function among community dwelling adults aged 65 years and over. The upper limb program focused on improving strength, mobility and function using dumbbell weights and resistance bands. The primary outcome was upper limb function measured by the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.[35] Secondary outcomes included shoulder strength and range of motion, physical activity and quality of life. The primary outcome of upper limb function showed no statistically significant difference between the two groups at 12 months. Most secondary outcomes did not change as a result of the intervention, although the lower limb group had slightly better shoulder strength on the left side at three months.

Despite the lack of measurable improvements in upper limb function, the trial demonstrated that older adults can successfully learn and adhere to a home-based exercise program with minimal supervision. The findings provide a starting point for further research and highlight the need to identify optimal exercise protocols for preventing shoulder dysfunction in older adults, especially given the growing prevalence of shoulder pain and its impact on independence, mobility and quality of life.[18,30]

There are certain groups of older people who are at a higher risk of falling. Older people with COPD have a higher risk of falls than their healthier peers, due to poorer balance, reduced muscle strength and exercise capacity. People with COPD also face more barriers in attending in-person programs, due to breathlessness, fatigue and the needs for use of supplemental oxygen.[36] Home-based exercise may be a more suitable option for people living in the community with COPD,[37] but has yet to be fully explored. **Chapter Six** begins to address this knowledge gap with a pilot study of a home-based exercise program for preventing falls in older adults with COPD enrolled in a virtual care service. The pilot study aimed to determine the effects of a home-based exercise program on balance, strength and fear of falling; and to understand the acceptability and feasibility of incorporating a home-based exercise program into a virtual care program for people with COPD.[38] The intervention is fully described using the Template for Intervention Description and Replication (TIDieR) checklist.[27]

The program was associated with significant improvement in lower limb function over the six-month period and showed a high level of acceptability and feasibility. Adherence was sub-optimal, with participants only completing the exercises on average twice per week for the duration of the program, rather than the specified frequency of three times per week. However, possibly due to reduced muscle strength and deconditioning in people with COPD, this was enough to show significant improvements in strength and balance at follow-up. Home-based exercise appears to be both safe and suitable for older adults with COPD. Future versions of the home-based exercise fall prevention program evaluated in the feasibility study could include offering participants a choice in the method of delivery (e.g. paper-based exercise manual versus digital/online version) based on their personal circumstances and preferences. Further research should be carried out to confirm these findings and incorporate strategies to enhance adherence.

7.4. Implications for practice

Chapters Three, Four and **Five** demonstrate that home-based exercise programs are feasible to teach via group-based workshops and are acceptable to a real-world population of older adults residing within both urban and regional centres in Australia. By using a pragmatic approach, reflecting how interventions are delivered in real-world settings, this also means that the findings are likely to be highly relevant for public health services operating with limited resources and aiming to implement cost-effective fall prevention strategies across diverse geographical areas.

Home-based exercise programs for older adults such as those investigated here align closely with global initiatives such as the United Nations Decade of Healthy Ageing (2021-2030)[39] and the World Health Organization's (WHO) Global Action Plan on Physical Activity (GAPPA) 2018-2030.[40] The United Nations Decade of Healthy Ageing emphasises enabling older adults to remain functional, independent and engaged in society.[39] Home-based exercise programs directly support several of its priority areas including promoting functional ability and intrinsic capacity; removing barriers to health and care, and supporting integrated and person-centred care.[39]

The WHO GAPPA aims to reduce global physical inactivity by 15% and encourages "active people, active societies, active environments and active systems."[2,40] Home-based exercise can fit within each of these pillars, however the most relevant fit is in Create Active People by promoting access to opportunities and programs to help people of all ages and abilities to engage in regular physical activity.[40] Home-based exercise programs expand opportunities for

older adults with mobility limitations, chronic conditions and/or caregiving responsibilities. They can also support older adults to meet the physical activity guidelines of 150-300 minutes plus strength and balance training.[2]

The review and research findings presented here support the assertion that there is an urgent need to investigate strategies to enhance implementation and scale-up of effective exercise-based fall prevention interventions into routine care of older people by healthcare professionals and community organisations.[41] Not all older people want to or are able to access community-based exercise programs,[37,42] with up to 50% of older adults preferring to exercise at home versus elsewhere.[43] This means that innovative approaches are required to combat the low rates of physical activity participation by older people.[4,44,45]

7.4.1. Prioritise provision of home-based exercise programs for older adults

The review of the literature found that home-based exercise programs have the potential to meet the need of those who prefer to exercise individually rather than in group settings, as many people favour exercising on their own and within their own homes.[42,43] They are also well suited to those living in regional and remote areas where access to appropriate group- or centre-based exercise options is limited or non-existent.[6,29] For individuals who require low- or no-cost programs, home-based exercise options can help overcome financial barriers, as the costs associated with attending in-person programs often prevent regular participation. Some people cannot afford these expenses, while others prefer subsidised or free alternatives.[6,37,42,43] Home-based programs also benefit those with limited or no access to transport, including older adults who do not have their own transport or lack convenient public transport options.[6,42] They may be particularly valuable for people who are new to

exercise, as having no previous exercise habit is a known barrier to program attendance, and exercising at home may help build confidence.[7] Home programs can also accommodate individuals who are caring for a frail partner or grandchildren, responsibilities that often take priority over attending structured exercise sessions.[6,7] It has also been documented that home-based exercise is often preferred by people who have recently fallen or who are concerned about falling, particularly those with mobility-related disability.[6,7,37,42]

7.4.2. The role of health professionals in promoting physical activity

This thesis highlights the potential of home-based exercise to increase physical activity levels in older adults. Evidence suggests that home-based exercise programs are more effective when instructed by a health professional.[8] Physiotherapist-led interventions have been shown to improve adherence to home-based exercise programs.[46] Additionally, a personal invitation from a health professional can facilitate participation in an exercise program.[47] Building strong connections with health care providers and keeping them informed about local programs is essential to boosting exercise participation among older adults. This approach enables health care providers to identify individuals at risk of falls and refer them to suitable exercise programs. Given that most older adults see their health care provider at least once a year, this referral pathway presents an opportunity to increase uptake of physical activity.[48]

7.4.3. Equity of access

Home-based exercise provides an equity focus by reaching those in rural areas, socially disadvantaged and with mobility limitations. Home-based exercise programs are generally more affordable for individuals compared to group-based classes, enhancing accessibility for those with lower incomes. Ensuring equitable access to such programs is essential to prevent

the widening health disparities between socioeconomically advantaged and disadvantaged populations.[43] Home-based exercise programs have the potential to be highly scalable by providing simple, low-cost interventions that can be delivered via printed materials, videos, apps or telehealth.[9] It is also possible to adapt the exercises to local contexts and cultural practices.[49]

7.4.4. Changing life circumstances

Depending on an individual's circumstances, home-based exercise programs may suit some people better at different stages of life due to changing lifestyle demands (e.g. caring for another individual, other responsibilities, recovering from illness, transport, location etc).[6,7] This may be dynamic, and an individual may change between these according to their needs and obligations at the time. This reinforces the needs to provide a wide variety of options for physical activity for older people if we want to increase the proportion of older people meeting the recommendations for physical activity.

7.4.5. Enhance adherence to home-based exercise

A key factor associated with the effectiveness of any exercise program is adherence to the program. Program characteristics and personal preferences may increase adherence to home-based exercise programs and therefore improve outcomes.[46,50] Factors shown to increase adherence to home-based exercise programs include physiotherapist-led delivery of the intervention, a balance exercise component and a moderate level of home visit support.[46] Personal preferences should be considered when providing options for exercise for an older adult, including how well an exercise program fits in with the lifestyle of an individual.[50]

Provision of additional support may also improve adherence to home-based exercise programs. Best practice guidelines for preventing falls released in 2025 recommend using a person-centred approach and involving older adults in the decision-making and goal setting for exercise plans, respecting their preferences and individual capacity.[29] Therefore, any additional support should be determined in consultation with the individual. Additional support could be telephone calls, text messages, occasional group or individual sessions, home visits, technology (apps), online groups or a coaching service. . This should be considered in future iterations of home-based exercise programs for older adults.

7.4.6. Use of digital technology

The WHO Global Strategy on Digital Health 2020-2025 aims to use digital technologies to improve health outcomes for everyone and to ensure that digital health solutions lead to more equitable and universal access to quality healthcare services.[51] Further exploration of the use of digital technology to assist with the implementation of home-based exercise programs for older adults should be supported. He et al examined the use of digital technology in delivering the OEP and found that its digital implementation led to significant improvements in balance, strength and falls self-efficacy among older adults.[52] Older adults may face barriers to accessing services, particularly due to remote locations and limited availability. Supporting virtual care approaches, such as telehealth, can help provide support from health professionals and deliver fall prevention interventions when appropriate.[29]

7.4.7. A starting point for those who have not exercised recently

Findings support previous research showing that participants are more likely to demonstrate improvements on key outcomes if their baseline level is low.[53] This would be the case for an

older adult who has not exercised for a period of time, has become deconditioned or has a chronic health condition. By improving function and self-efficacy, and using ongoing coaching or follow-up, it is possible that home-based exercise programs could be an avenue into more mainstream or supervised exercise programs as the participant progresses and builds their confidence and physical functioning. Therefore, with the appropriate support, home-based exercise could be considered a pathway to further supervised exercise programs which then may be able to provide greater long-term benefit to the individual.

7.5. Methodological strengths and limitations

7.5.1. Strengths

The overall strength of this research is the rigorous methodology used to test the interventions. A prospectively registered randomised controlled trial design followed CONSORT[54] reporting standards and used robust procedures to minimise bias. The randomisation was performed using a computer-generated sequence with concealed allocation, and outcome assessors were blinded to group allocation. The prospective trial registration and a pre-published protocol enhanced the transparency and reproducibility of the research.

The randomised controlled trial included a large and well-powered sample. With a sample size of 617 community-dwelling older adults enrolled, the trial exceeded the calculated sample size needed to detect a clinically relevant reduction in falls. The broad inclusion criteria and recruitment from community settings reflect a real-world population of older adults who may take up similar exercise programs. Participants in the COPD pilot trial were recruited through a free regional health service and were receiving their care via a virtual care

platform. These participants were older people with a confirmed COPD diagnosis from their medical practitioner, rather than the healthy volunteers often seen in other trials.[55,56] This makes them a more representative for the potential future implementation of a home-based exercise program. The pragmatic design of the interventions had an emphasis on efficiency and potential scalability.

Another important strength was the use of validated, standardised outcome measures. Falls were measured using monthly calendars supported by follow-up phone calls, which is considered best practice for falls research.[57] Secondary outcomes, such as the Falls Efficacy Scale, Short Physical Performance Battery and accelerometry are well-established, reliable tools related to fall risk. The home-based exercise intervention for the lower limb used an existing evidence-based fall prevention program that was initially implemented as a one-on-one exercise program delivered individually via home visits.

A further strength lies in the feasibility and acceptability of the intervention. The program was delivered by experienced physiotherapists in local community venues, making it a realistic and scalable alternative to more resource intensive home-visit models, potentially allowing for greater reach. Participants reported high levels of confidence, satisfaction and willingness to continue the exercises, with the majority indicating they would recommend the program to peers. Such acceptability is crucial for community-based fall prevention initiatives, where uptake and sustained engagement is often a challenge.

7.5.2. Limitations

Difficulty recruiting the participants who we assumed would benefit most from a home-based exercise program was a significant limitation of the trial reported on in **Chapters Four, Five and Six**. For example, those with low levels of physical activity and unable to access traditional centre- or group-based exercise programs were particularly hard to reach. Like many other clinical trials,[55,56] participants who self-selected to participate in this randomised controlled trial were a healthier cohort who appeared to be more active at baseline than the general older population. As a result, the exercises may not have provided enough challenge.

When working with the population of participants with COPD, recruitment was much more challenging indicating the complexity of working with a population with a life-limiting chronic condition. Participants with COPD were more difficult to recruit into the pilot and sessions often needed to be rescheduled due to illness and hospitalisation. A rise in COVID cases during the recruitment period may have made this group more hesitant to join a new program that required some in-person sessions.

The interventions were only conducted with participants who had proficiency in the English language to engage with the program and program materials. This excluded people from culturally and linguistically diverse populations. People with cognitive impairment and progressive neurological conditions (e.g. Parkinson's disease) were also excluded from the trial. These groups often have higher rates of falls and could benefit from such an intervention, however there are often methodological, safety and practical issues that need to be considered when working with these groups. These populations can also introduce

variability in outcomes due to differences in functional, cognitive and behavioural profiles, which complicates the interpretation of the intervention effects.

While the BEST at Home intervention demonstrated high acceptability, its limited impact on falls may reflect insufficient integration of behaviour change theory and sustained support mechanisms. Although elements consistent with Social Cognitive Theory were present, such as instruction and self-monitoring, the absence of ongoing reinforcement, feedback, and social support may have contributed to suboptimal adherence and failure to achieve the exercise dose required for preventing falls.

The COM-B is a behaviour change framework that conceptualises behaviour as the result of interactions between capability, opportunity and motivation.[58] The COM-B model provides a useful framework for understanding exercise adherence. In this study, while capability and opportunity were addressed, limited support for motivation may explain suboptimal adherence and the lack of effect on falls.

The workshop-based delivery model, while scalable, may have diluted key components of effective programs such as progression and supervision, highlighting a trade-off between reach and efficacy. Furthermore, the relatively healthy, active, and self-selected cohort limits generalisability, particularly to more vulnerable populations who may face greater social and structural barriers to participation. Future research should adopt theory-informed and co-designed approaches, incorporating qualitative methods to better understand engagement, and explore alternative delivery models such as hybrid interventions to enhance long-term adherence and effectiveness.

The sub-optimal levels of adherence need to be acknowledged as a limitation of the studies presented. As raised earlier in this Chapter, adherence could be addressed by including targeted behaviour changes strategies, using a person-centred approach and involving older adults in the decision-making and goal setting for exercise plans.

A formal cost-effectiveness analysis was not undertaken because the intervention did not demonstrate a statistically or clinically meaningful effect on the primary outcome. In the absence of evidence of effectiveness, a full economic evaluation is unlikely to provide meaningful estimates of value for money. We acknowledge that this decision limits the economic interpretation of our findings. Future research may consider economic evaluation if modifications to the intervention result in improved effectiveness.

7.6. Conclusion

Falls and upper limb dysfunction represent significant health issues among older adults. As the global population ages at an increasing rate, the strain on healthcare systems worldwide is anticipated to increase significantly. This highlights the urgent need for scalable interventions that promote physical activity participation among older adults to improve strength and balance and promote independence. Home-based exercise programs offer a practical approach to enhancing access to appropriate physical activity, supporting older adults to meet the recommended exercise guidelines.

The innovatively delivered and rigorously tested interventions presented in this thesis contribute to our understanding of effective strategies to improve strength, balance, physical function and fall prevention in older adults. The interventions that were tested were both acceptable to participants and feasible to deliver. They are particularly valuable when directed toward individuals who would benefit most, such as those with low physical activity levels, reduced strength and balance, older age or chronic health conditions. This thesis also provides recommendations to guide future research, inform program development, and enhance the availability of exercise opportunities that support the well-being of the growing older adult population.

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APPENDIX A:
BEST at Home - Exercise program manual for the lower body

BEST at home

Balance Exercise Strength Training

Welcome to the home-based exercise program

Please mark on the calendar each day you do an activity, as shown below. If you have a fall, record this as well.

F if you have a fall, then the time and place of the fall

D if you see a Doctor (write GP or Specialist)

H if you are admitted to hospital

E When you do the exercises

Each day that you have paid community health services (not family or friends) mark it on the calendar.

S showering

C cleaning

M meals

T transport and/or shopping

N Nurse

O Physiotherapist, Occupational Therapist or Podiatrist (please specify)

Even if there is nothing to mark on the calendar for that month, please check the box that says ‘I had no falls this month’.

The exercise program that you will undertake has been designed specifically for you.

Exercise has many benefits. By maintaining your exercise program, you can improve:

- Balance
- Muscle strength
- General fitness
- General well-being.

Please try to do your exercises three times each week.

You can divide the exercises up. They do not all have to be done at the same time.

Between each set of exercises take three deep breaths or more.

You may feel a bit stiff after you first start to exercise. This is quite normal. It is because you are using muscles which may not be used to the exercise. It is important that you keep on exercising. The stiffness will leave as your body becomes more familiar with the exercise.

Getting stronger by using weights

Strengthening your muscles is essential for maintaining healthy bones and muscles necessary for walking and being independent in your daily activities.

- Lift the weight slowly through the entire range of movement.
- Never hold your breath while lifting. Inhale before lifting, exhale while lifting and inhale again while lowering the weight.

Safety

- Never exercise holding onto an object which may move, for example a chair.
- Always use the side of something stable like a bench or solid table unless otherwise instructed.
- Always ensure the floor area is clear of clutter and obstacles before starting the exercises.

Contact your doctor if while exercising you experience:

- Dizziness
- Chest pain
- Shortness of breath (you are unable to speak because you are short of breath).

If you have any questions about the exercise program please do not hesitate to telephone the BEST at Home research team on (02) 4221 6778.

Day to day

Did you know that you can improve your general fitness simply by being more active in your day-to-day life?

Here are some examples of activities to build into your day:

- Walk instead of driving to the shops
- Walk to talk to a neighbour instead of phoning
- Take the stairs rather than the lift or escalator
- Get off the bus a block early and walk home
- When visitors and family arrive, go for a walk with them before having a cup of tea
- Garden when the weather permits
- Stand to fold washing.

Helpful hints

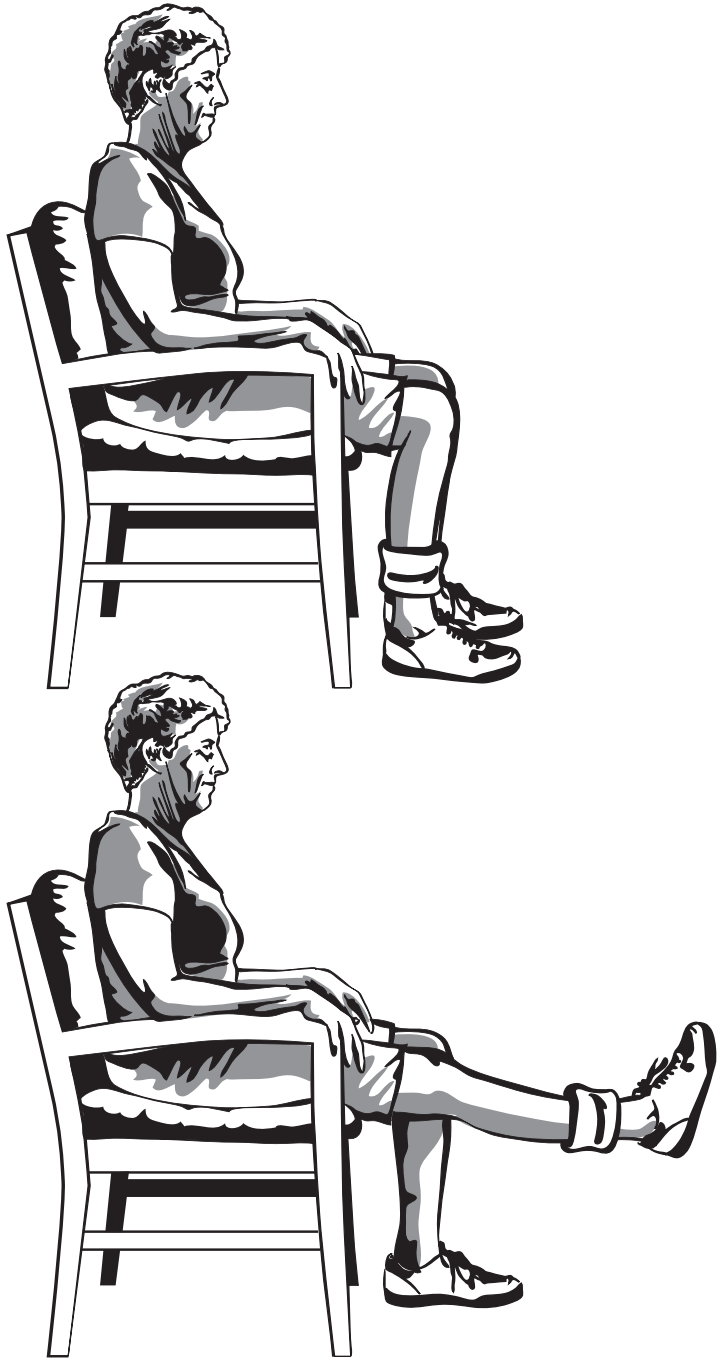
Here are some hints, to help you complete the exercises three times per week.

- Keep this manual in an easy to see place as a reminder.
- You do not need to do all the exercises all at once. You can break up the exercises into smaller portions and complete throughout the day. You just need to make sure that by the end of the day you have completed all the exercises.
- If you complete the exercises in smaller portions, leave the manual open to the exercise you are up to.
- Try to incorporate the exercises into your daily routine, for example:
    - front knee strengthening exercise while watching TV
    - calf or toe raises while waiting for the kettle to boil
    - heel toe walking down the hallway
    - knee bends while talking on the telephone etc.
- Use the calendar provided to keep track of when you complete the exercises.
- Tell friends and/or family members about your exercises and ask them to support you to do the exercises.
- Think about the benefits of improved strength and balance.

- Reward yourself for completing all the exercises at the end of the month.
- Read *'Staying active and on your feet'* for tips on how to stay safe and independent in your home.
- It can be easy to fall out of an exercise routine due to holidays or ill health. Try not to be discouraged, start up the exercises again and slowly get back into your regular routine.
- Going away? Take your manual and weight with you. It is easy to pack and it will help to keep you in a routine if you continue while on holidays.
- Too easy? Think about the different ways the physiotherapists suggested you could make the exercises harder. For example:
    - Do more repetitions of the exercise
    - Hold the exercise contraction for longer
    - If you feel confident, use less support.

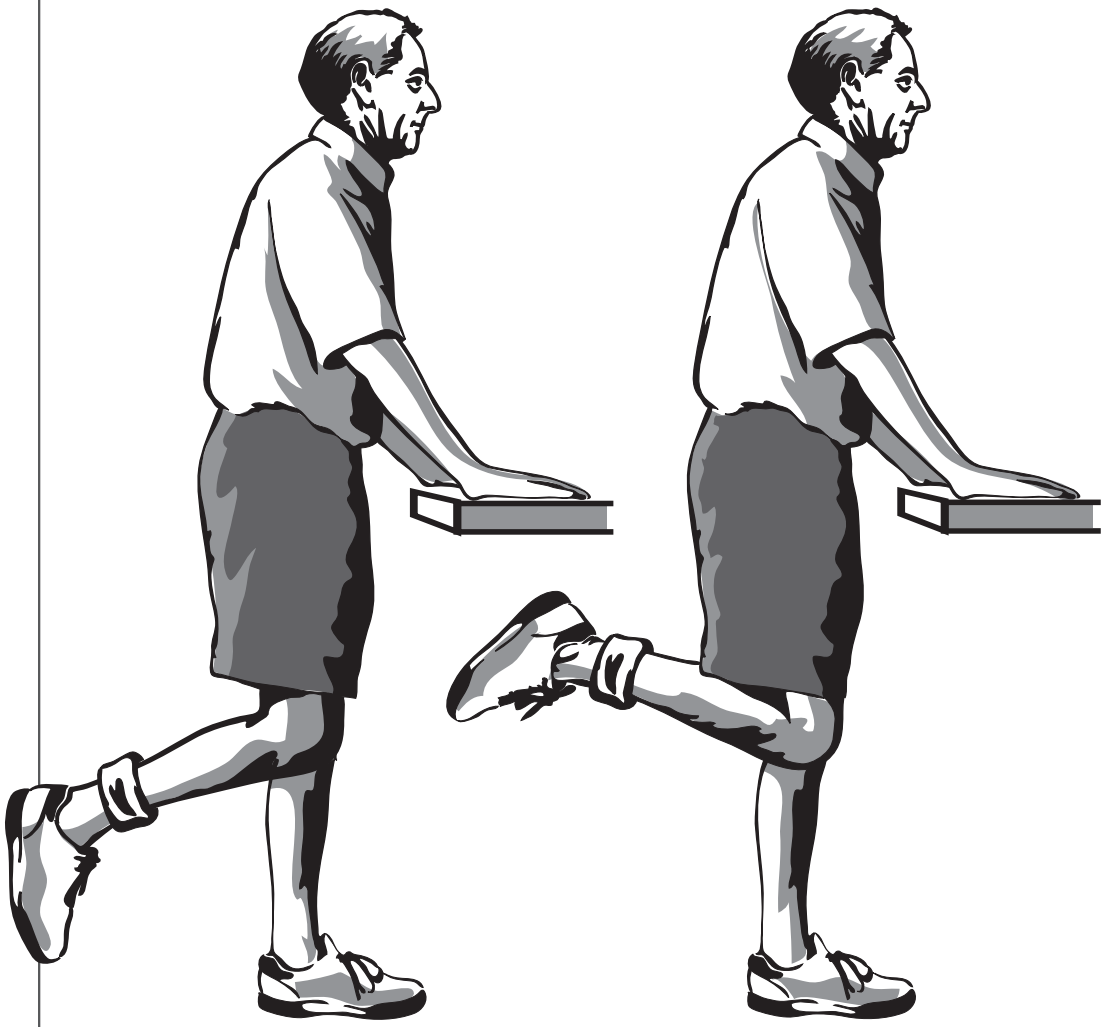
Front knee strengthening exercise

- You could do this exercise while you are watching TV
- Strap the weight on to your ankle
- Sit on a chair with your back well supported
- Straighten the leg out
- Lower the leg
- Repeat ◯ times
- Strap the weight on to the other ankle
- Repeat this exercise ◯ times



Back knee strengthening exercise

- Strap the weight on to your ankle
- Stand up tall facing the bench with both hands on the bench
- Bend the knee, bringing the foot towards your bottom
- Return to the starting position
- Repeat ◯ times
- Strap the weight on to the other ankle
- Repeat this exercise ◯ times

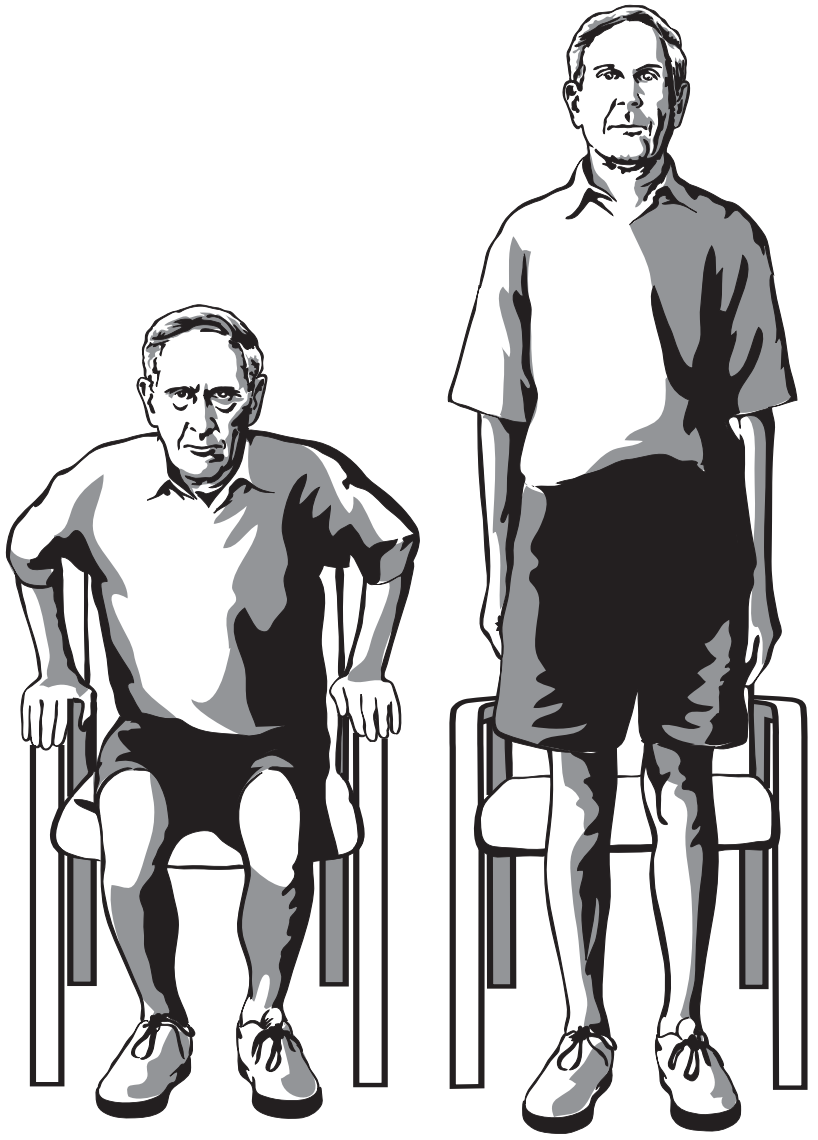


Side hip strengthening exercise

- Strap the weight on to your ankle
- Stand up tall beside the bench
- Hold on to the bench
- Keep the exercising leg straight and the foot straight forward
- Lift the leg out to the side and return
- Repeat ◯ times
- Strap the weight on to the other ankle
- Turn around
- Repeat this exercise ◯ times

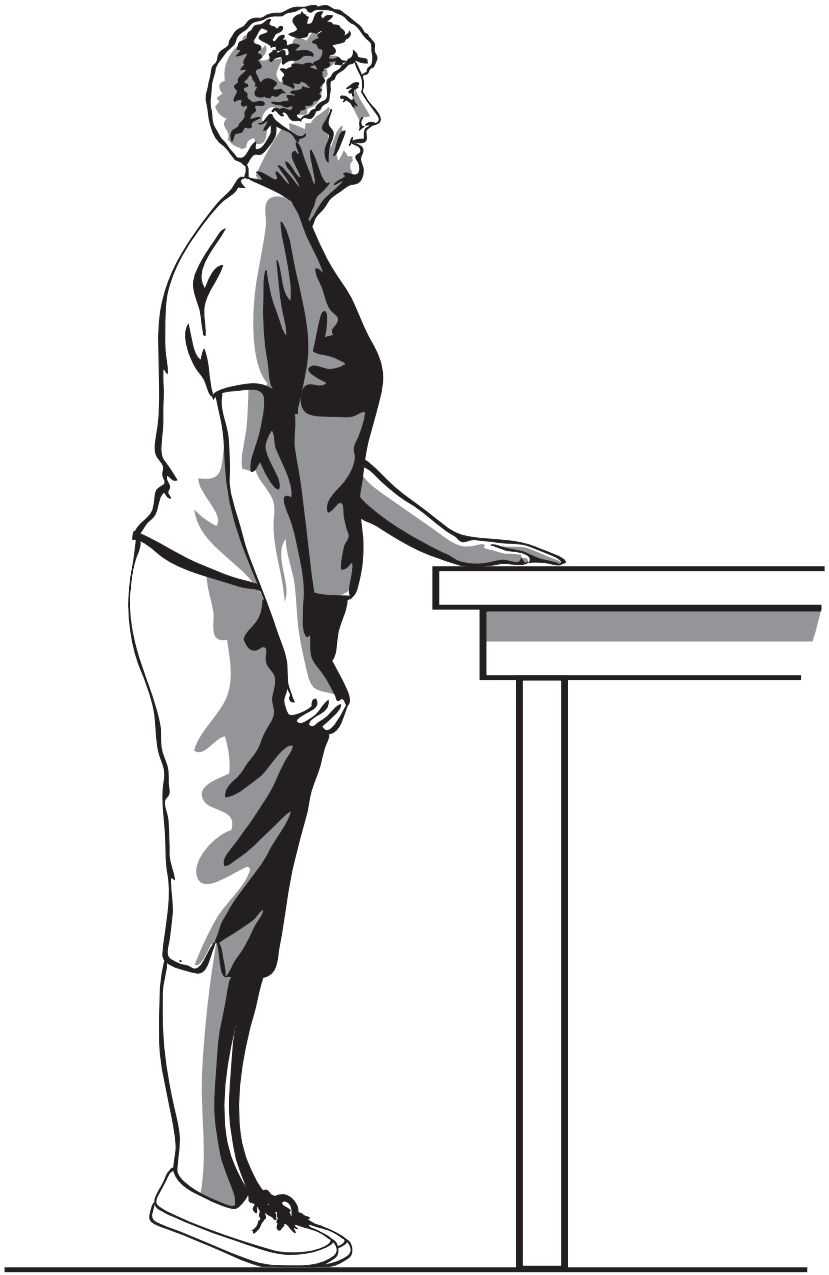
Sit to stand – two hands

- You could do this exercise while you watch TV
- Sit on a chair which is not too low
- Place the feet behind the knees
- Lean forwards over your knees
- Push off with both hands to stand up
- Repeat ◯ times



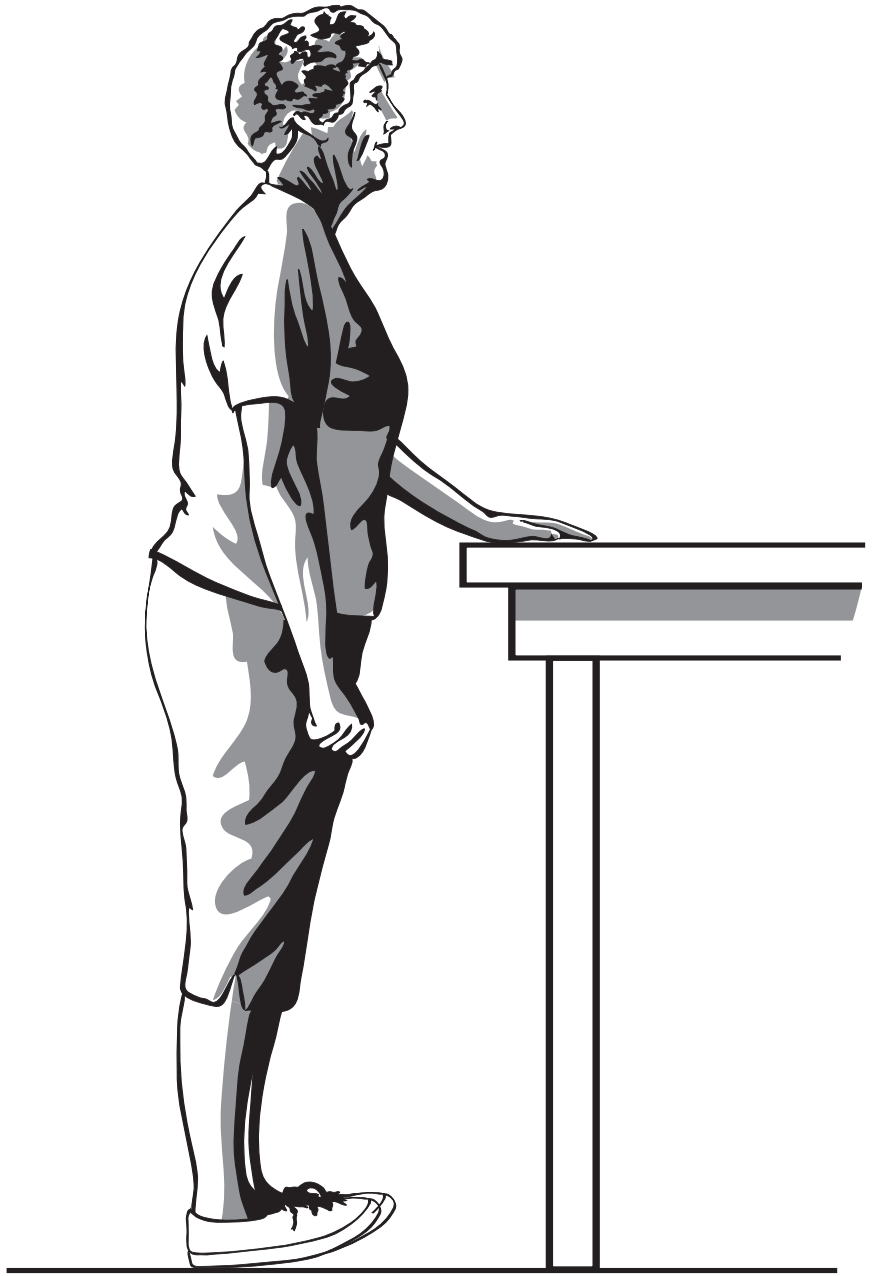
Calf raises – hold support

- Stand up tall facing the bench
- Hold on and look ahead
- The feet are shoulder-width apart
- Come up onto your toes
- Lower the heels to the ground
- Repeat this exercise 20 times



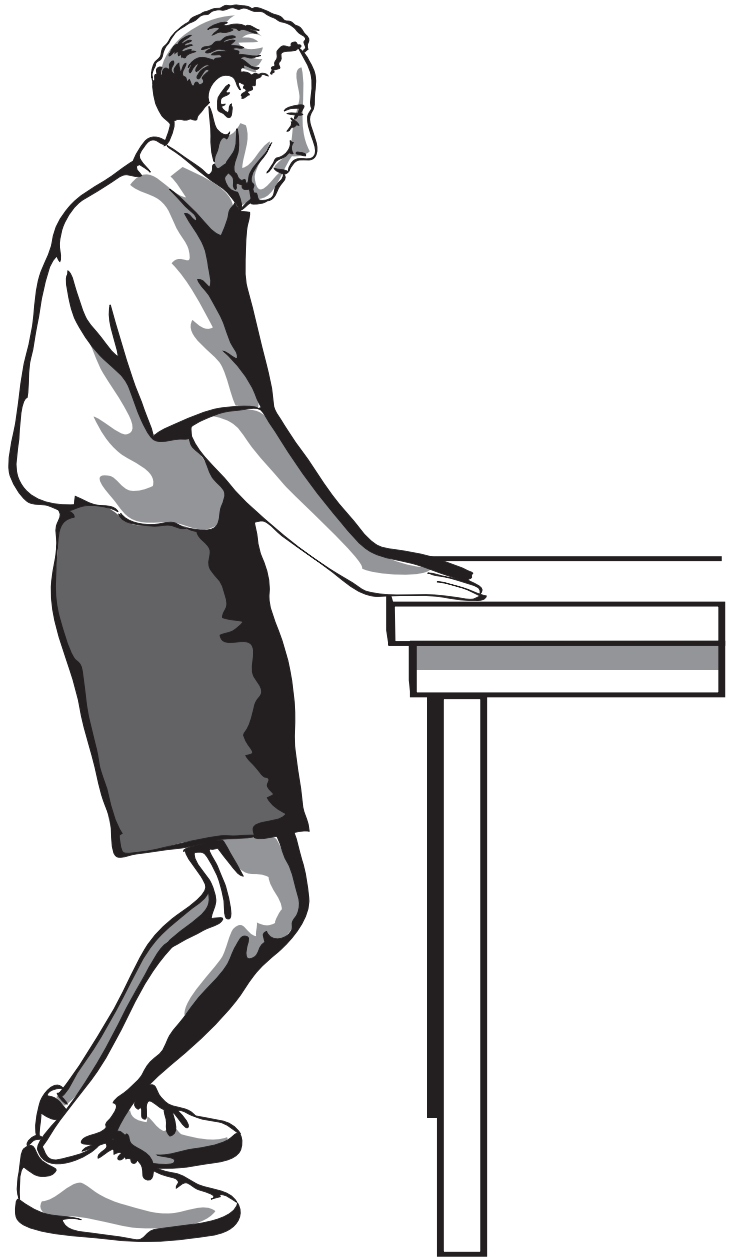
Toe raises – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- The feet are shoulder-width apart
- Come back onto the heels, raising the front foot off the floor
- Lower the feet to the ground
- Repeat this exercise 20 times



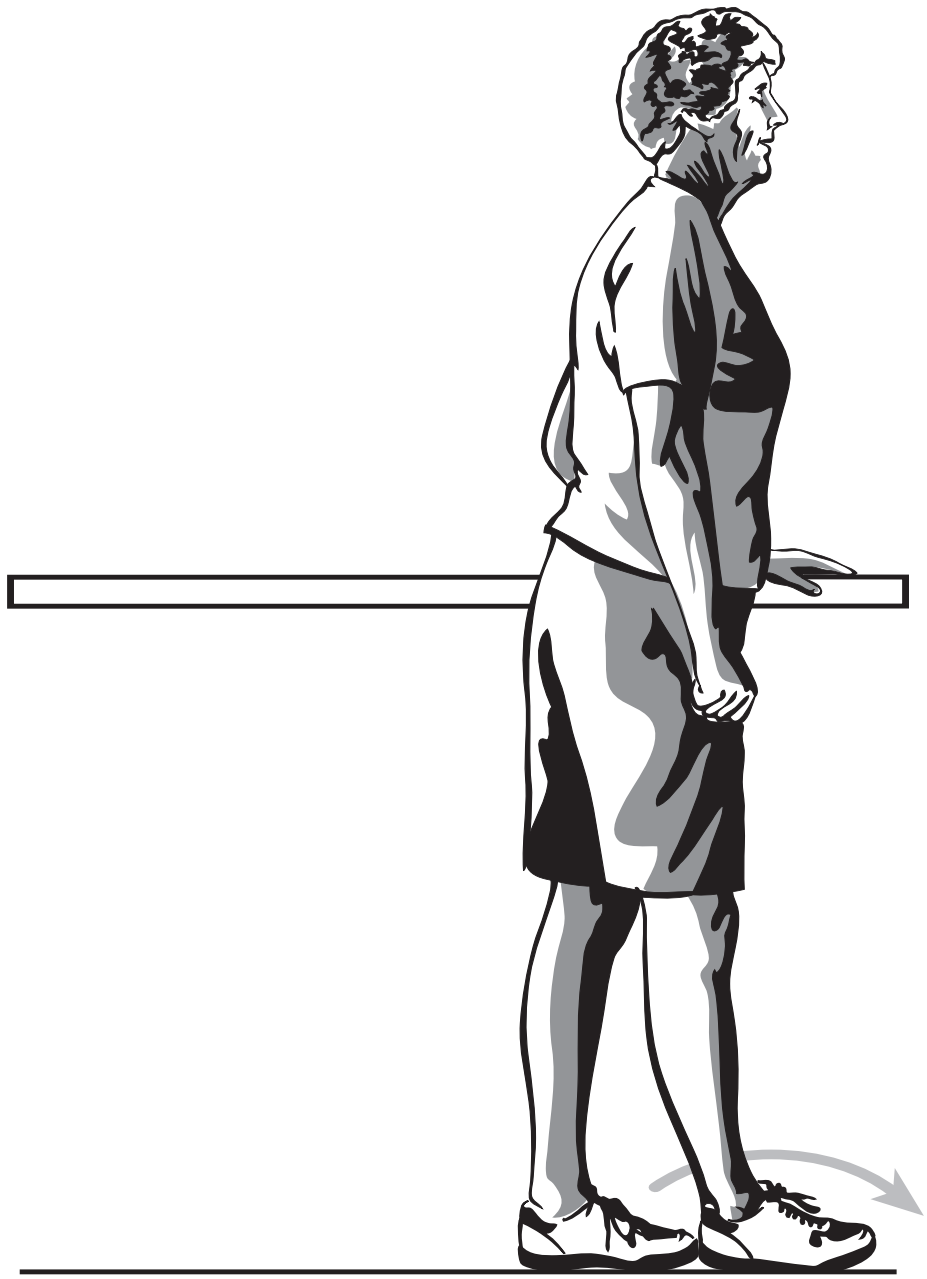
Knee bends – hold support

- Stand up tall facing the bench with both hands on the bench
- Place your feet shoulder-width apart
- Squat down half way, bending your knees
- The knees go over the toes
- When you feel your heels start to lift, straighten up
- Repeat ◯ times



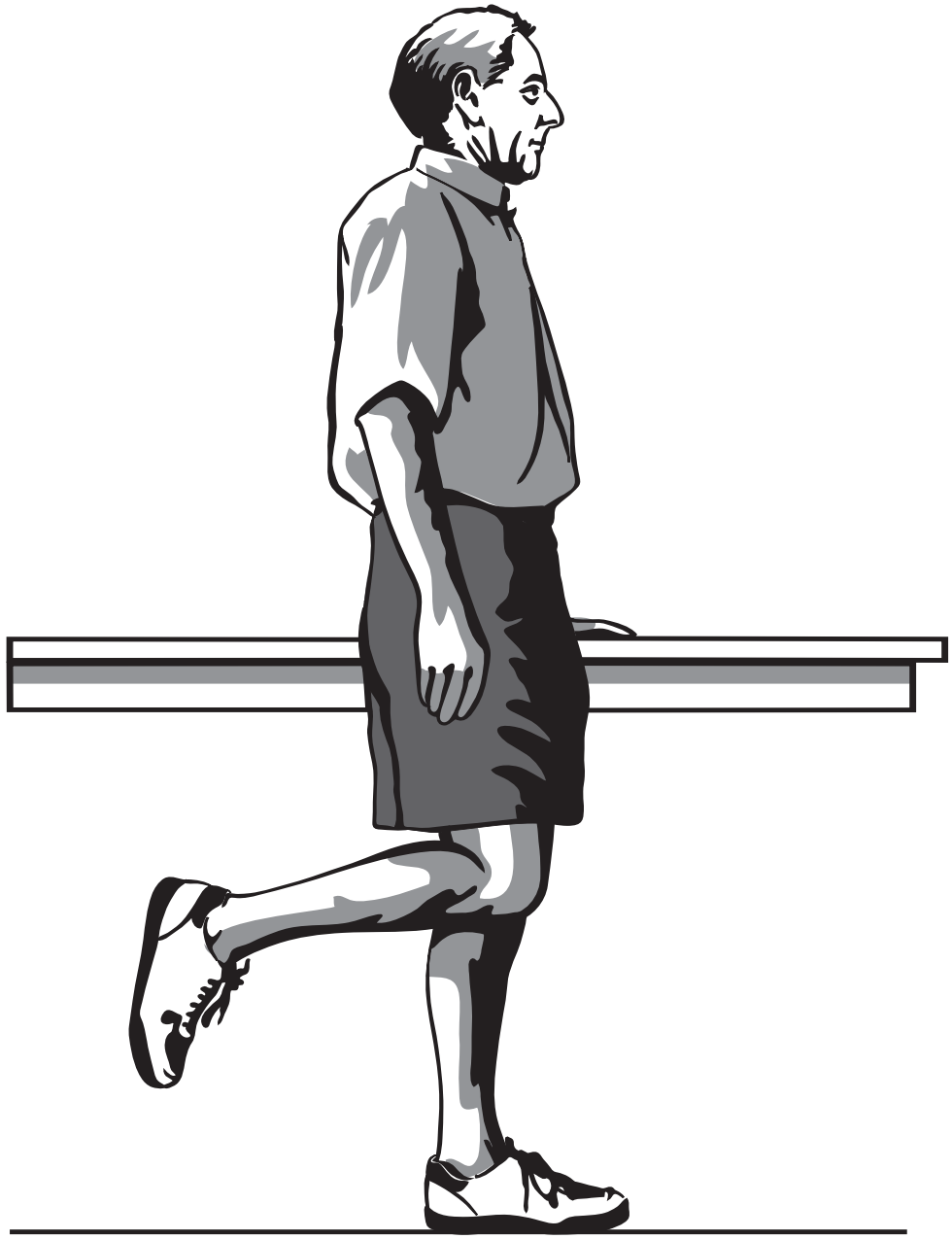
Heel toe standing – hold support

- Stand up tall beside the bench
- Hold on to the bench and look ahead
- Place one foot directly in front of the other foot so the feet form a straight line
- Hold this position for 10 seconds
- Change position and place the foot behind directly in front
- Hold this position for 10 seconds



One leg stand – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Stand on one leg
- Try to hold this position for 10 seconds
- Stand on the other leg
- Try to hold this position for 10 seconds

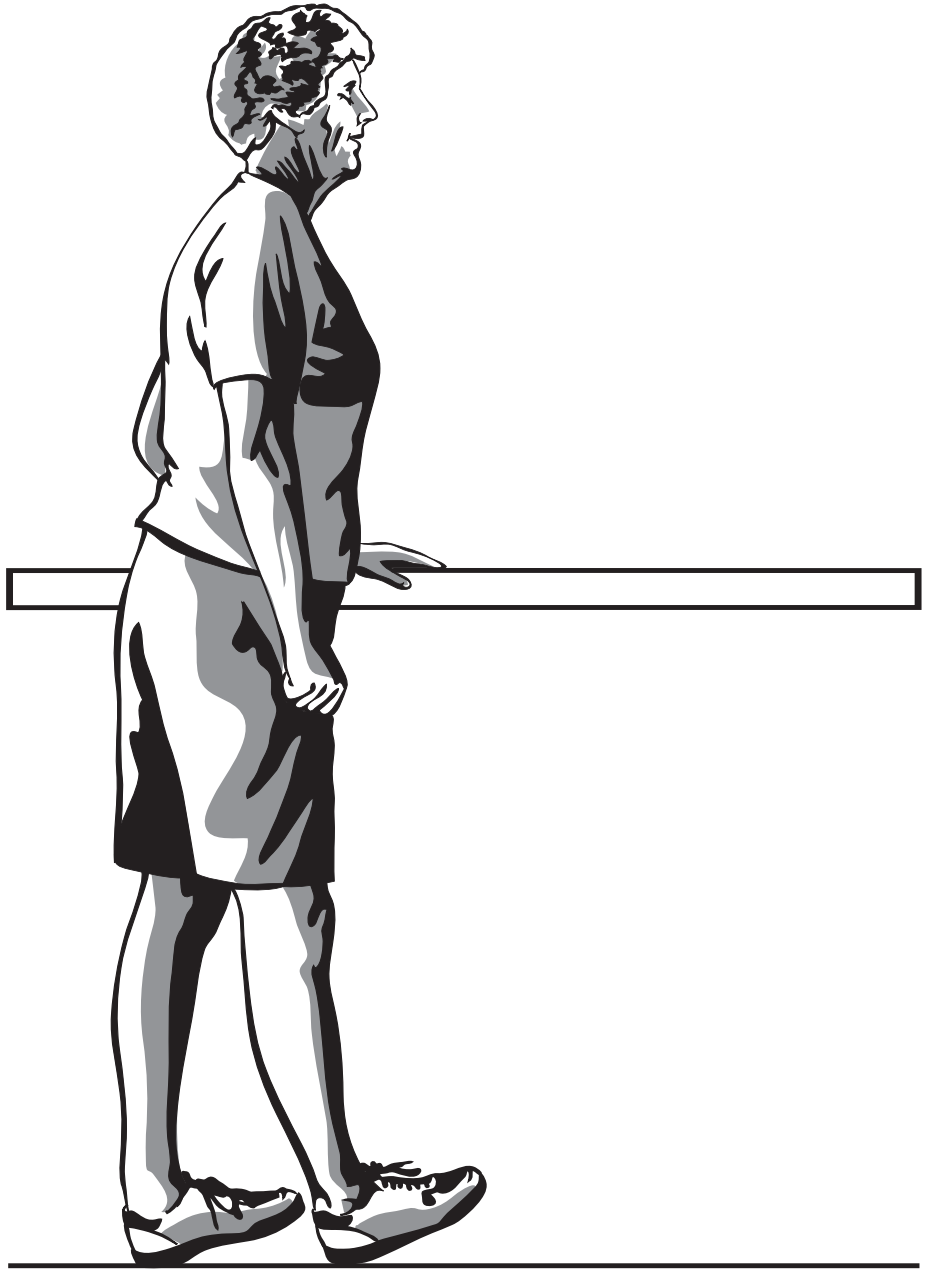


Sideways walking

- Stand up tall and place your hands on your hips
- Take 10 side steps to the right
- Take 10 side steps to the left
- Repeat

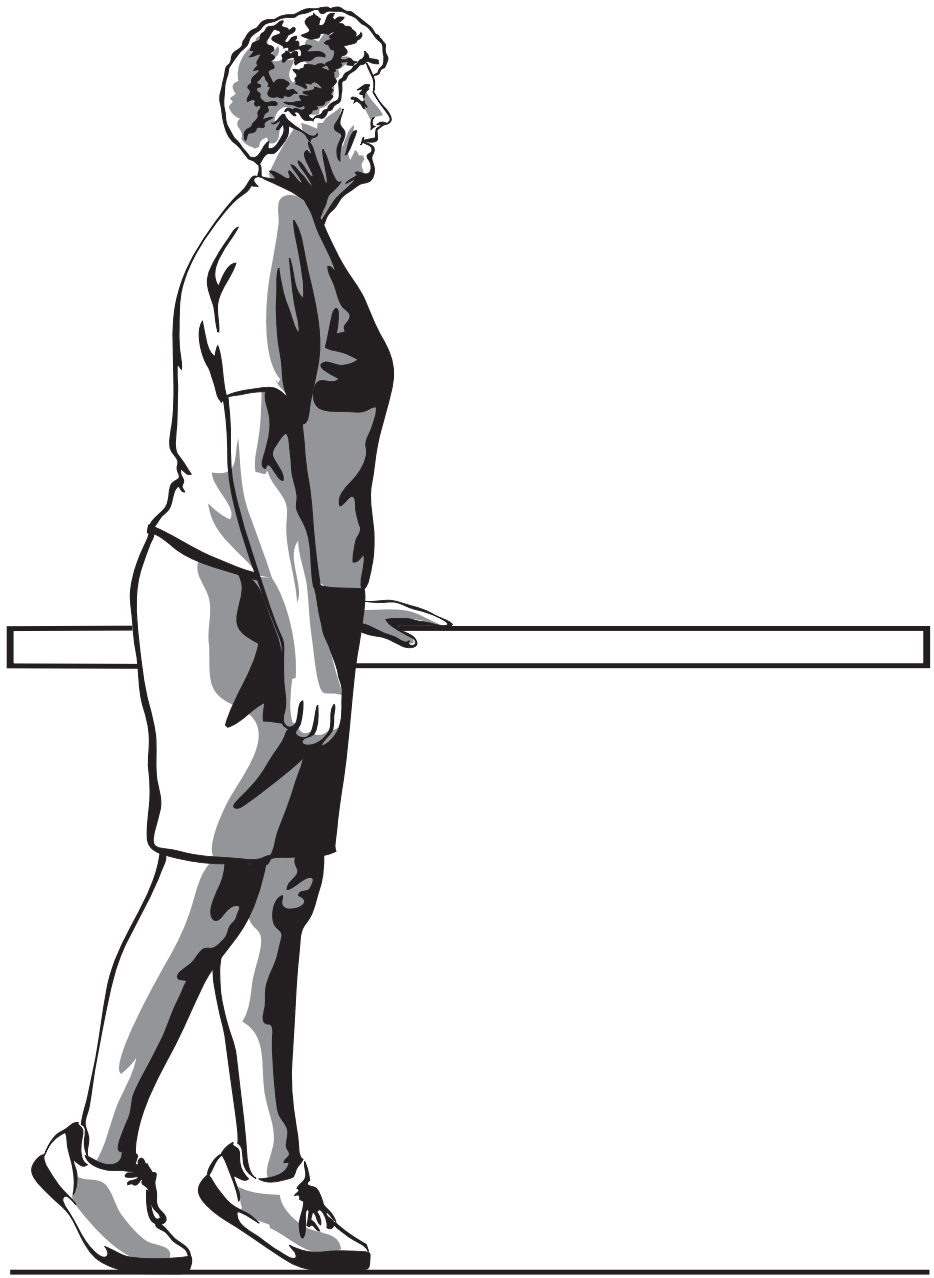
Heel walking – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Come back onto the heels, raising the front foot off the floor
- Walk 10 steps on your heels
- Lower the feet to the ground and turn around
- Walk 10 steps on your heels
- Repeat



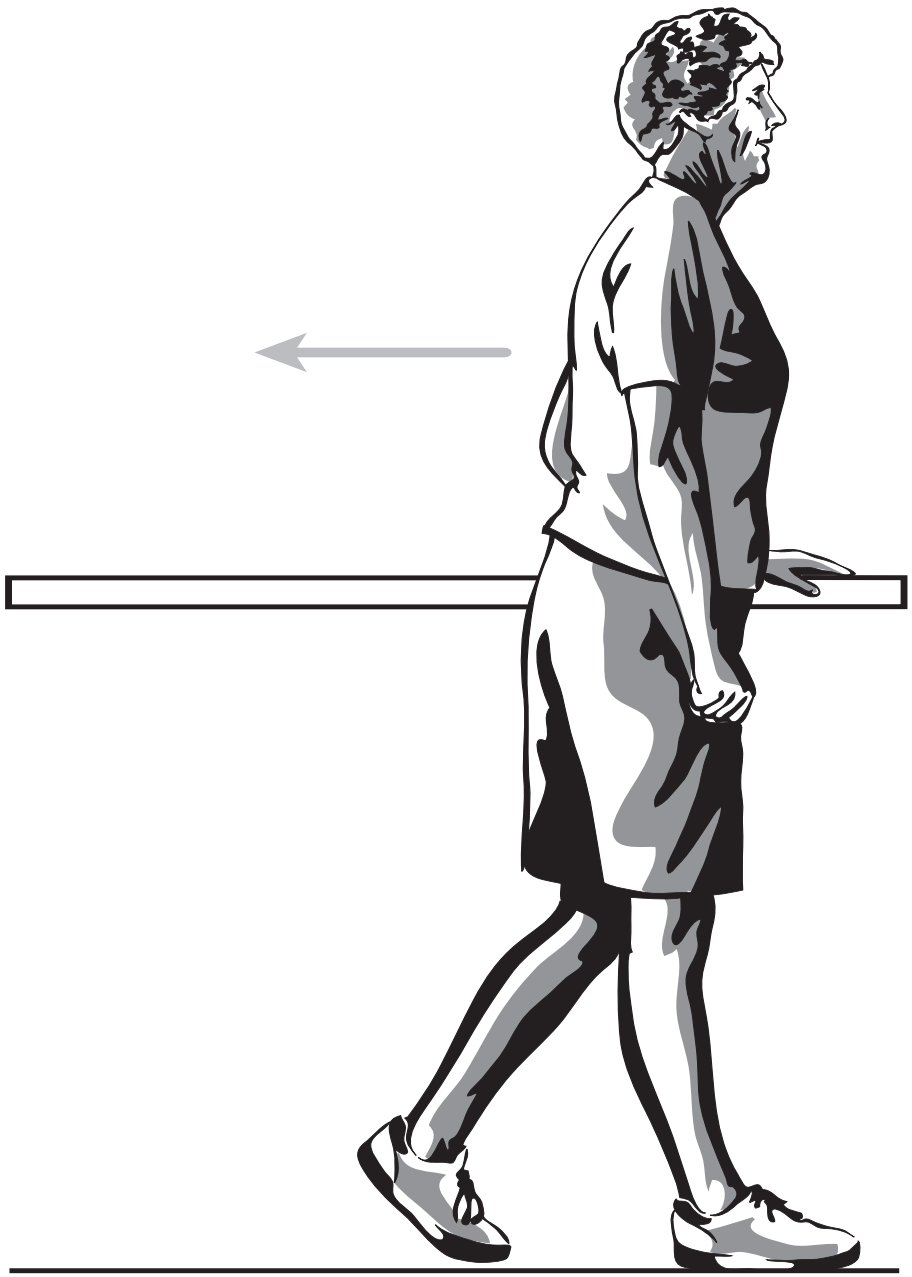
Toe walking – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Come up onto your toes
- Walk 10 steps on your toes
- Lower the heels to the ground and turn around
- Walk 10 steps on your toes
- Repeat



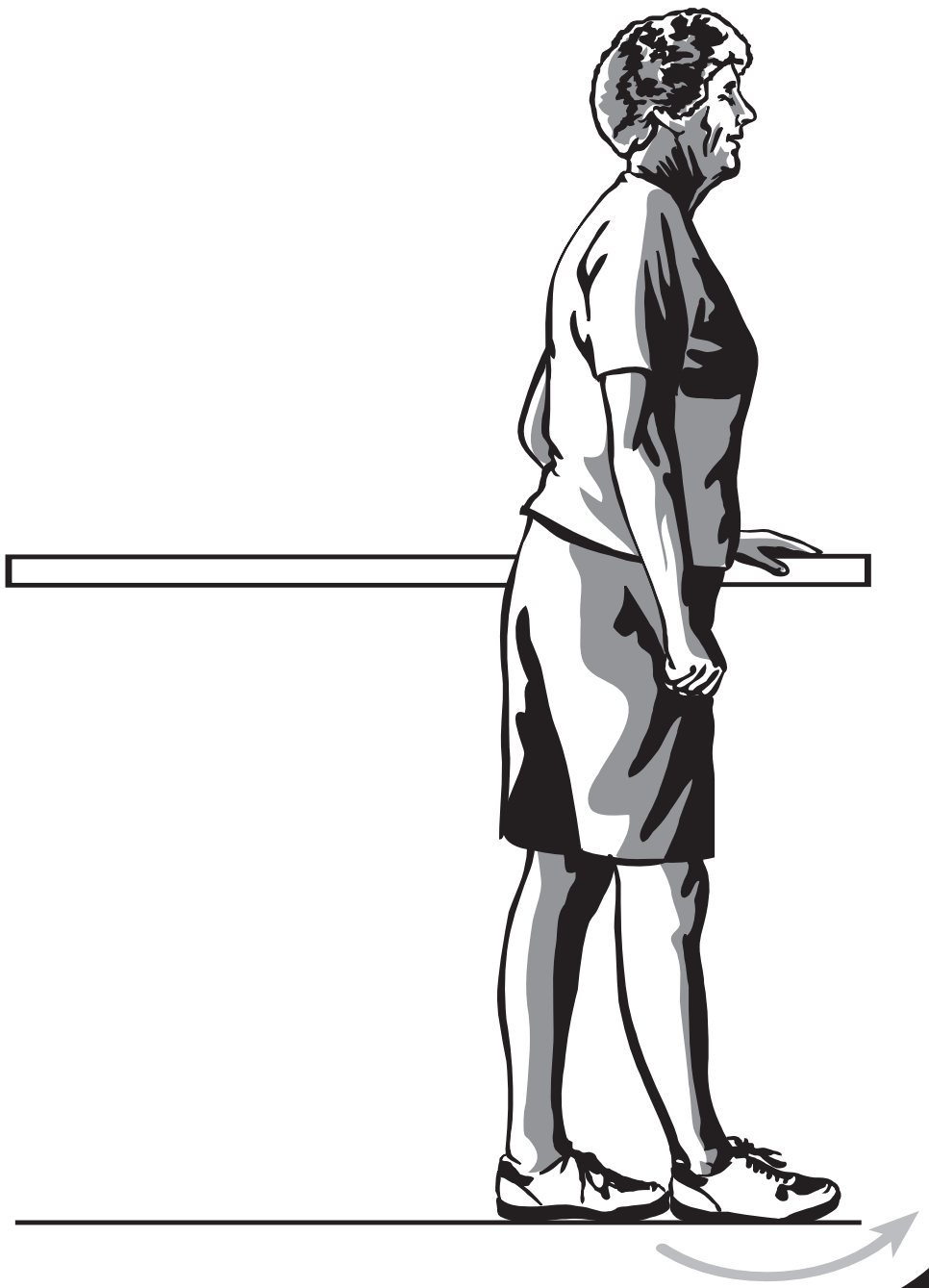
Backwards walking – hold support

- Stand up tall and hold on to the bench
- Walk backwards 10 steps
- Turn around and hold on with the other hand
- Walk backwards 10 steps to the beginning
- Repeat this exercise



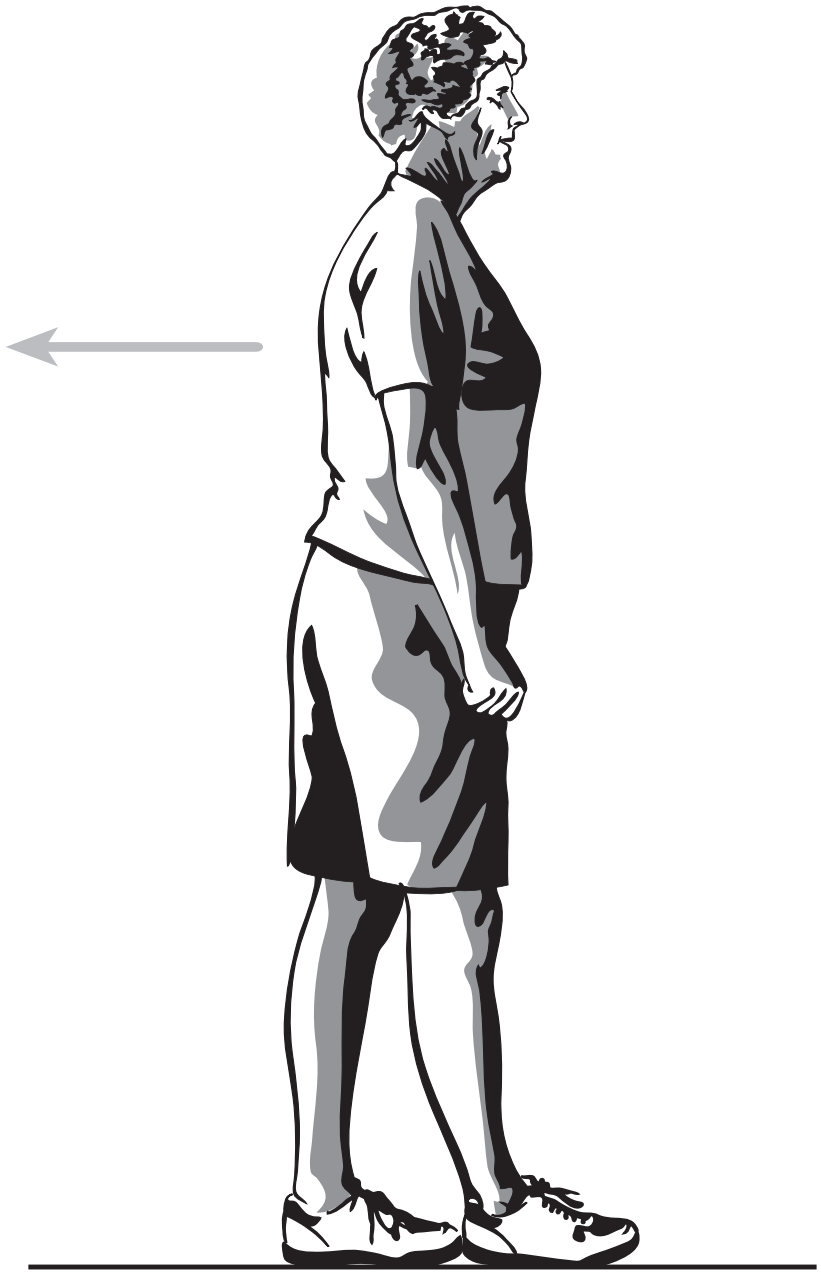
Heel toe walking – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Place one foot directly in front of the other so they form a straight line
- Place the foot behind directly in front
- Repeat for 10 more steps
- Turn around
- Repeat the exercise



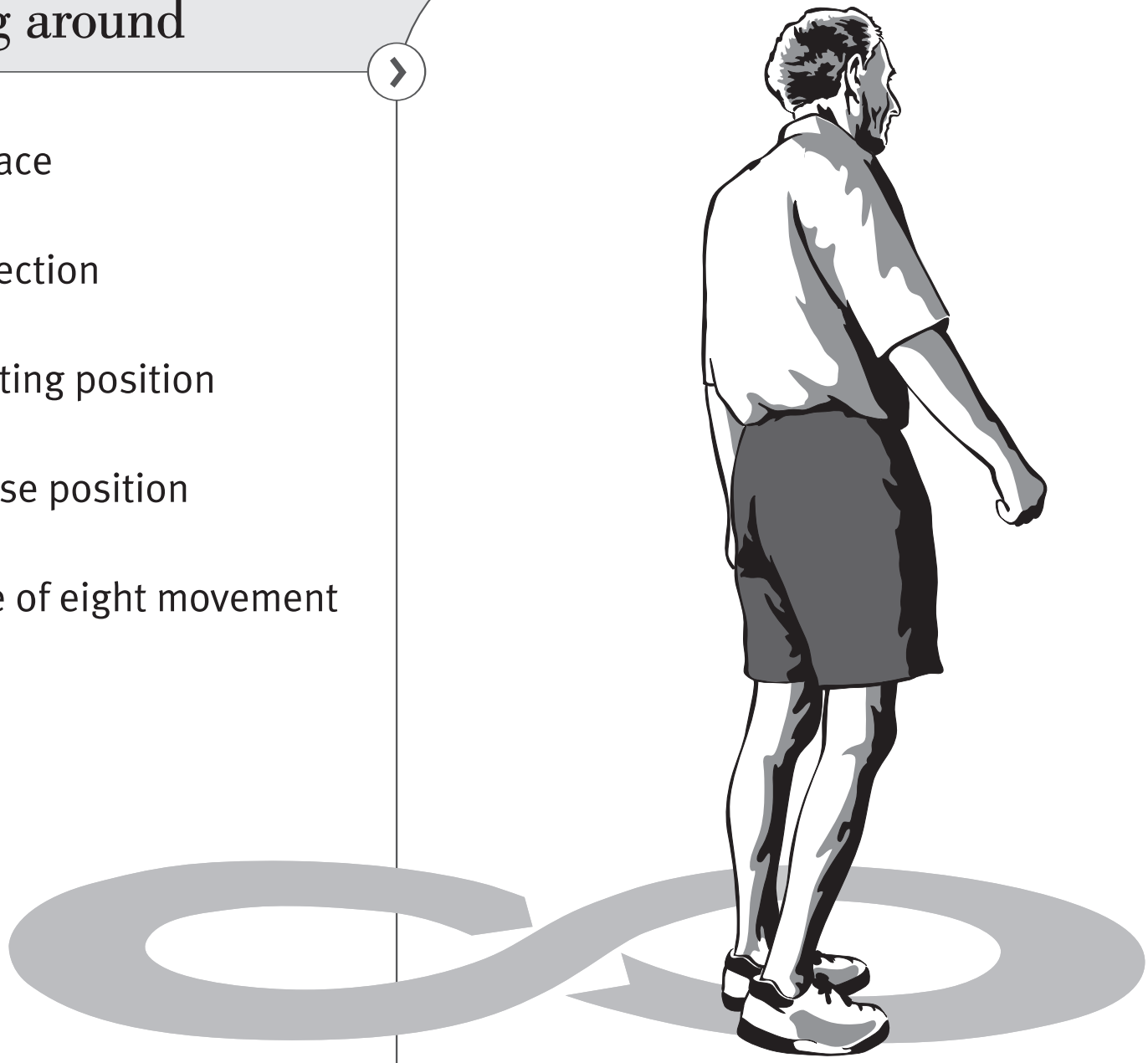
Heel toe walking backwards

- Stand up tall and look ahead
- Place one foot directly behind the other foot
- Place the foot in front directly behind
- Repeat for 10 more steps
- Turn around
- Repeat the exercise



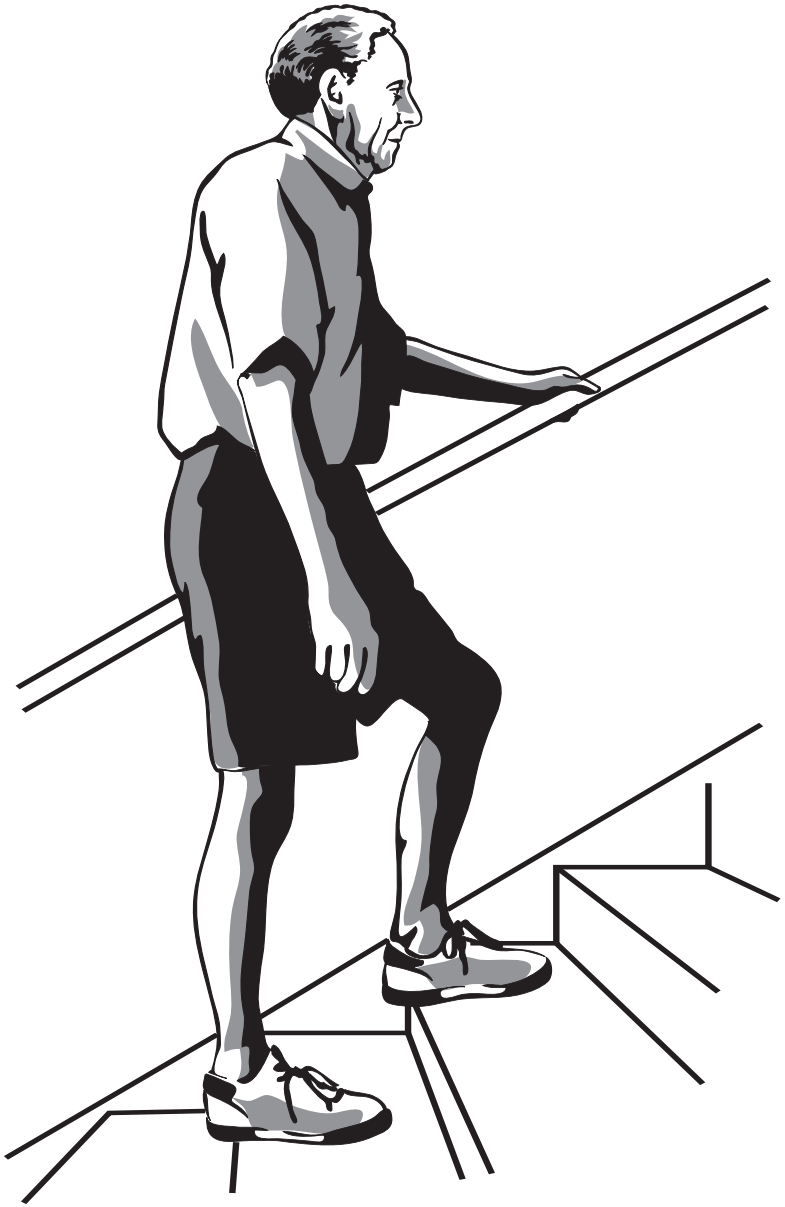
Walking and turning around

- Walk at your regular pace
- Turn in a clockwise direction
- Walk back to your starting position
- Turn in an anti-clockwise position
- The exercise is a figure of eight movement
- Repeat this movement



Stair walking

- Hold on to the hand-rail for this exercise
- Go up and down the stairs for ◯ steps



APPENDIX B:
BEST at Home - Exercise program manual for the upper body

BEST at home

Balance Exercise Strength Training

Welcome to the home-based exercise program

Please mark on the calendar each day you do an activity, as shown below. If you have a fall, record this as well.

F if you have a fall, then the time and place of the fall

D if you see a Doctor (write GP or Specialist)

H if you are admitted to hospital

E when you do the exercises

Each day that you have paid community health services (not family or friends) mark it on the calendar.

S showering

C cleaning

M meals

T transport and/or shopping

N Nurse

O Physiotherapist, Occupational Therapist or Podiatrist (please specify)

Even if there is nothing to mark on the calendar for that month, please check the box that says ‘I had no falls this month’.

The exercise program that you will undertake has been designed for you.

Exercise has many benefits. By maintaining your exercise program, you can improve:

- Shoulder function
- Muscle strength
- General well-being.

Please try to do your exercises three times each week.

You can divide the exercises up. They do not all have to be done at the same time.

Between each set of exercises take three deep breaths or more.

You may feel a bit stiff after you first start to exercise. This is quite normal. It is because you are using muscles which may not be used to the exercise. It is important that you keep on exercising. The stiffness will leave as your body becomes more familiar with the exercise.

Getting stronger by using weights

Strengthening your muscles is essential for maintaining healthy bones and muscles necessary for lifting and reaching and being independent in your daily activities.

- Lift the weight or pull the resistance band slowly through the range of movement.
- Never hold your breath while lifting. Inhale before lifting and exhale while lifting. Inhale again while lowering the weight.

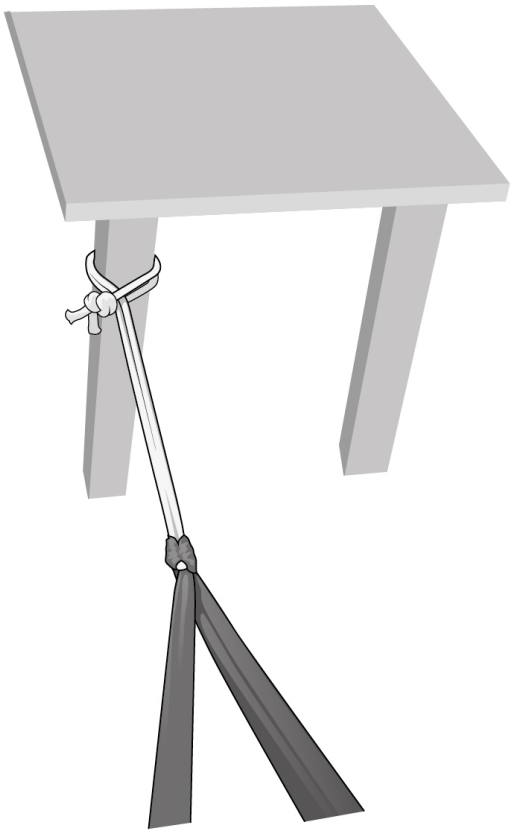
Arm exercise tips

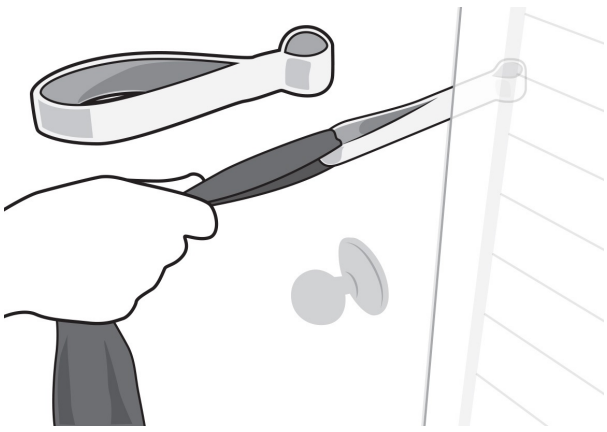
- The exercises should not be painful to do. They should not make your shoulder painful in the 12 hours after you have done them.
- The exercises should not make your shoulder click.
- When you do the exercises it is important to keep your shoulder blades back and down your back and keep your trunk still.
- When exercising with only one arm, hold on to the chair with your other arm.

If you have any questions about the exercise program please do not hesitate to telephone the BEST at Home research team on (02) 4221 6778.

Safety

- Always check your resistance band before use, especially near the attachment. Look for small nicks or tears that may cause the band to break. Discard the band and contact the BEST at Home research team for a new band, if you find any flaws.
- Be sure your resistance band is securely attached to a sturdy object before using.





- Do not overstretch the resistance band by more than three times its resting length. For example a 30cm band should not be stretched to more than 90cm total length.
- Protect the resistance band by keeping it away from sharp objects.
- Remove rings from fingers before using the resistance band. Be aware of long, sharp fingernails.
- Store your resistance band out of direct sunlight and away from extreme temperatures.
- Always make sure the floor area is clear of clutter and obstacles before starting the exercises.

Contact your doctor if while exercising you experience:

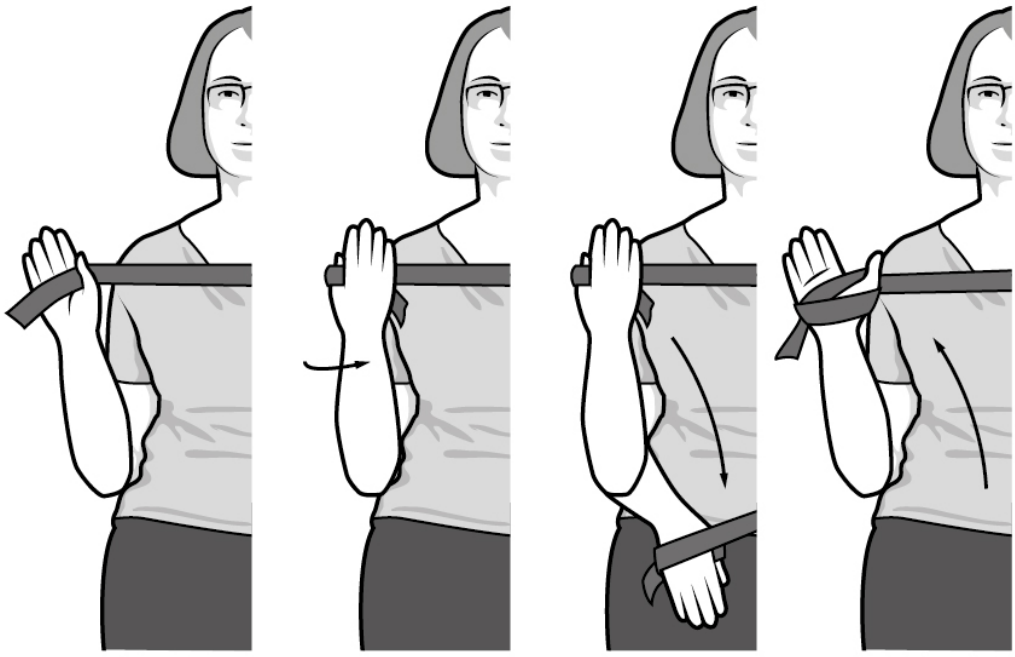
- Dizziness
- Chest pain
- Shortness of breath (you are unable to speak because you are short of breath).

How to hold your resistance band

Choose either:

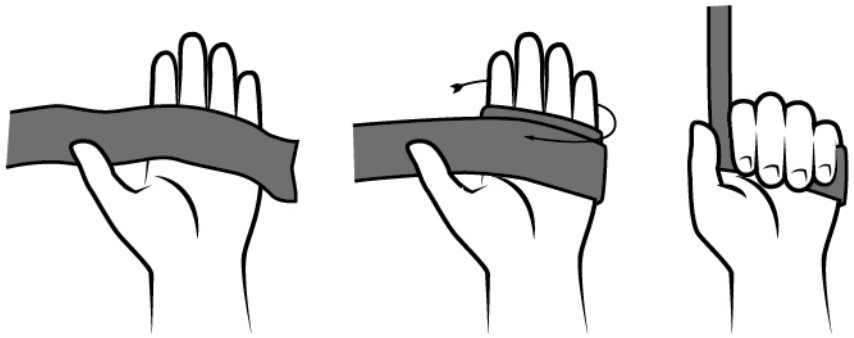
Rotation wrap

- Begin with your palm facing forward and the end of the band between the thumb and palm, pointing to your little finger.
- Rotate your palm inward.
- Turn your hand downward, bringing the band around the back of your hand.
- Return your palm facing forward, bringing the band between your thumb and fingers.
- Grasp firmly.



Grip wrap

- Lay the band flat in your hand with the end toward your little finger.
- Wrap the long end of the band around the back of your hand.
- Repeat as needed.
- Grasp firmly.



Helpful hints

Here are some hints, to help you complete the exercises three times per week.

- Keep this manual in an easy to see place as a reminder.
- You do not need to do all the exercises at once. You can break up the exercises into smaller portions and complete throughout the day. You just need to make sure that by the end of the day you have completed all the exercises.

- If you complete the exercises in smaller portions, leave the manual open to the exercise you are up to.
- Use the calendar provided to keep track of when you complete the exercises.
- Tell friends and/or family members about your exercises and ask them to encourage you to do the exercises.
- Think about the benefits of improved shoulder function.
- Reward yourself for completing all the exercises at the end of the month.
- It can be easy to fall out of an exercise routine due to holidays or ill health. Try not to be discouraged, start up the exercises again and slowly get back into your regular routine.
- Going away? Take your manual, band, attachment and weight with you. They are easy to pack and it will help to keep you in a routine if you continue while on holidays.
- Too easy? With shoulder exercises correct posture and shoulder positioning is essential. Concentrate on each exercise and make sure you are doing it correctly. If they are still too easy tell the BEST at Home research team at the next workshop and we will upgrade your exercises.

BEST at home

Balance Exercise Strength Training

Upper body exercise program

NSW GOVERNMENT Health
Illawarra Shoalhaven Local Health District

THE GEORGE INSTITUTE for Global Health AUSTRALIA

THE UNIVERSITY OF SYDNEY

kg WEIGHT L R

Elbow curl

1 Sit with your feet on the ground, shoulder width apart.

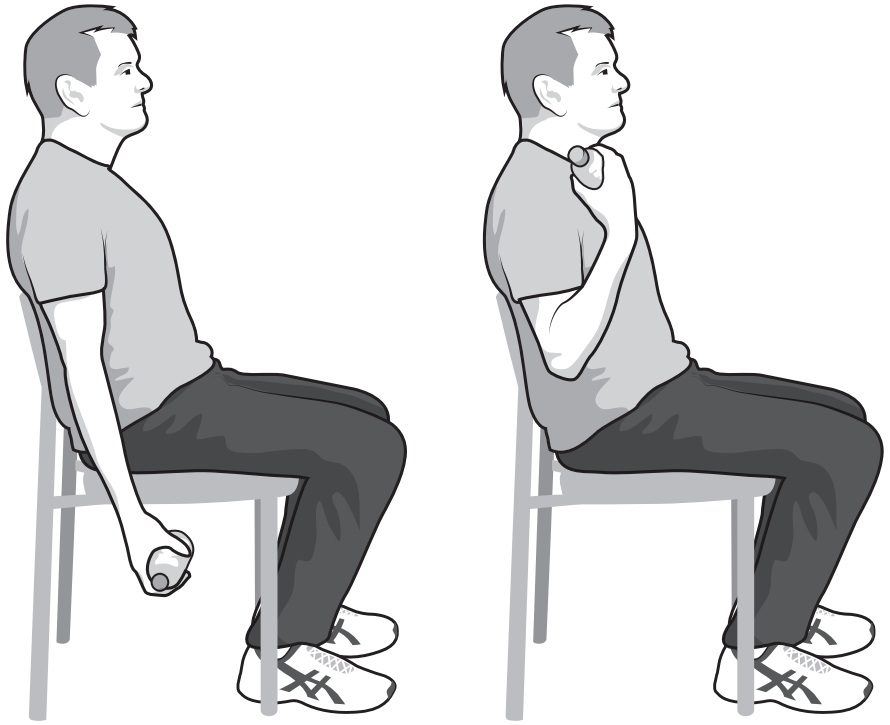
2 Hold your weights in both hands with your arms by your side.

3 Pull your shoulder blades back and down your back.

4 Slowly bend your elbows up as far as possible and then lower back down.

5 Make sure to keep your shoulder blades back throughout the movement.

6 Repeat 10 times.



kg WEIGHT L R

Elbow extension

1 In sitting, lean forward as far as you can with your left elbow resting on your knees.

2 Hold your weight in your right hand and take your elbow back as far as possible.

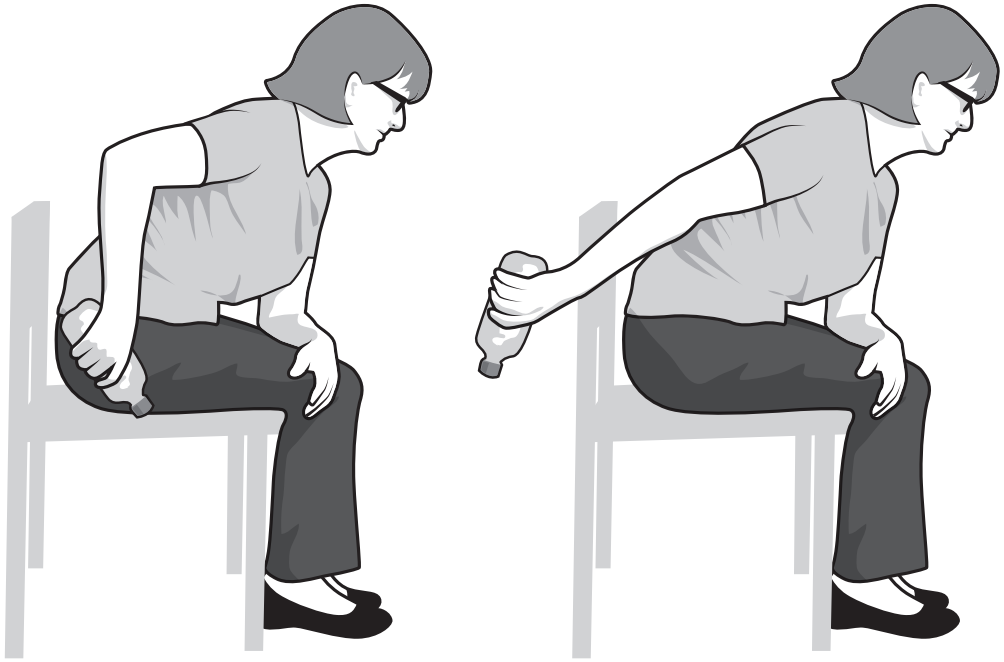
3 Pull your shoulder blades back and down your back.

4 Keeping your elbow back and still, slowly straighten your arm and then return to the starting position.

5 Repeat 10 times.

6 Swap weight to left hand and rest right elbow on knees.

7 Repeat 10 times left side.



Shoulder press

1 Sit with your feet on the ground, shoulder width apart.

2 Hold your hands facing forward, near your shoulders.

3 Pull your shoulder blades back and down your back.

4 Slowly straighten your elbows to lift your hands above your head and back to the starting position.

5 Make sure your shoulder blades do not lift up during the movement.

6 Repeat 10 times.

Arm raise

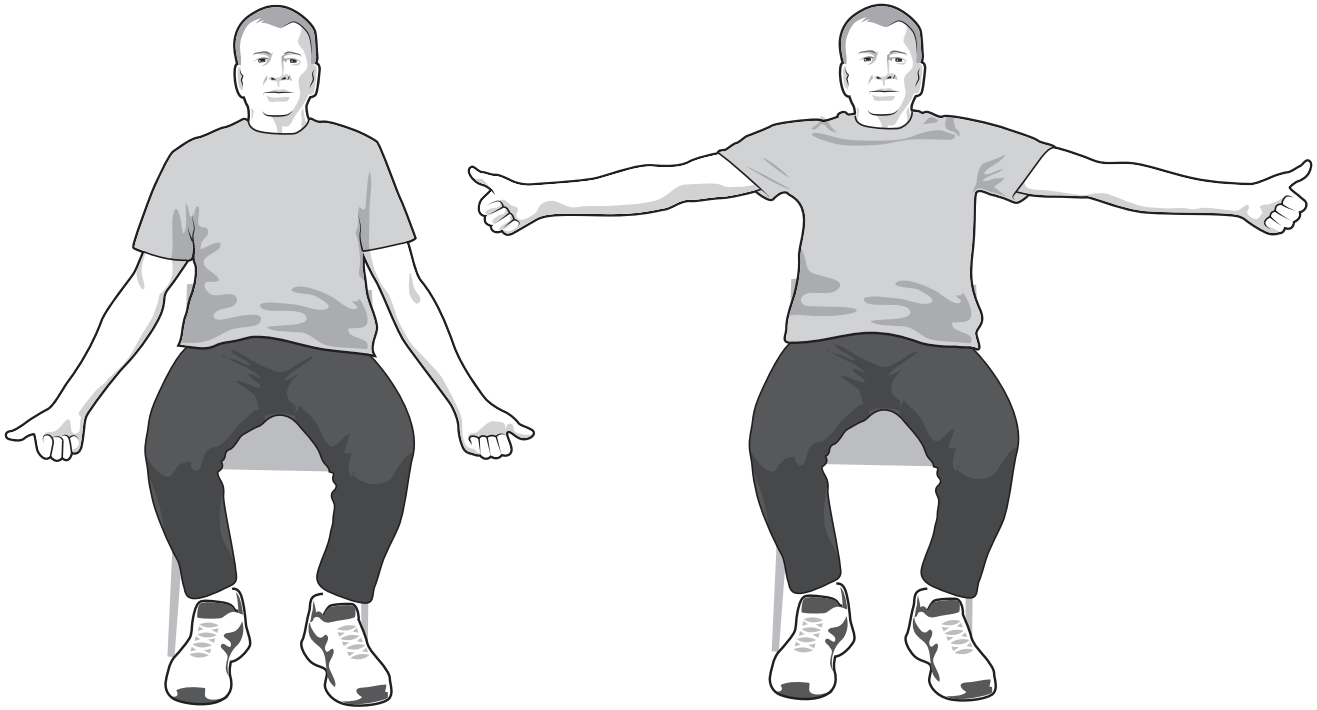
1 Sit with your feet on the ground, shoulder width apart and arms by your side.

2 Pull your shoulder blades back and down your back.

3 With your thumbs leading and your elbows straight, slowly lift your arms directly out to the side to just below shoulder height and return to your side.

4 Make sure your shoulder blades do not lift up during the movement.

5 Repeat 10 times.



kg WEIGHT L R

Chest press

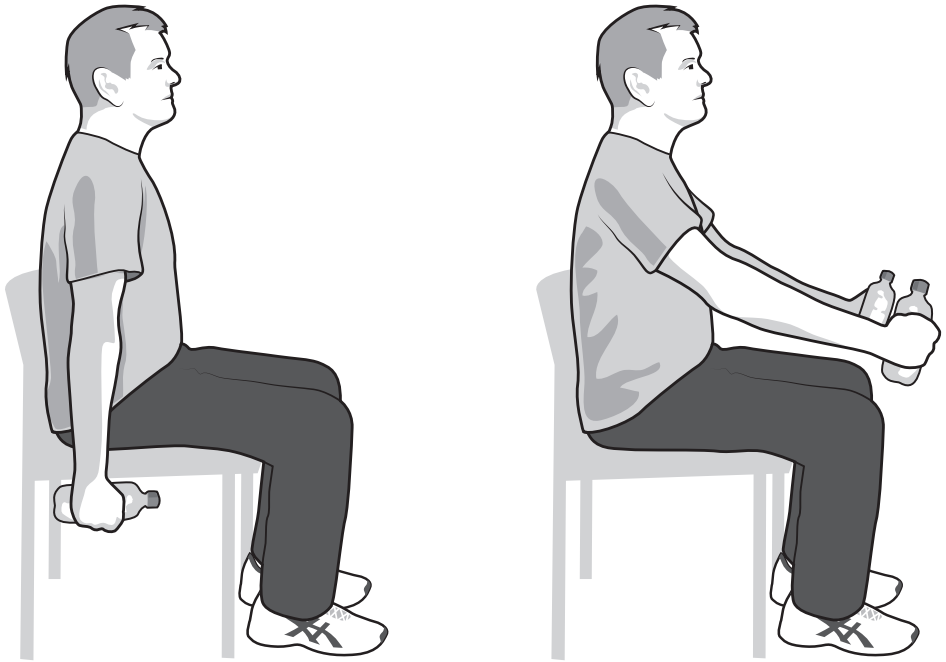
1 Hold a weight in both hands.

2 Start with your arms by your side.

3 Keeping your elbows straight slowly lift your arms forward to waist height and then back down again.

4 Make sure to keep your shoulder blades back and down throughout the movement.

5 Repeat 10 times.



Shoulder row

1 Attach band to a secure point eg rail, door, table leg.

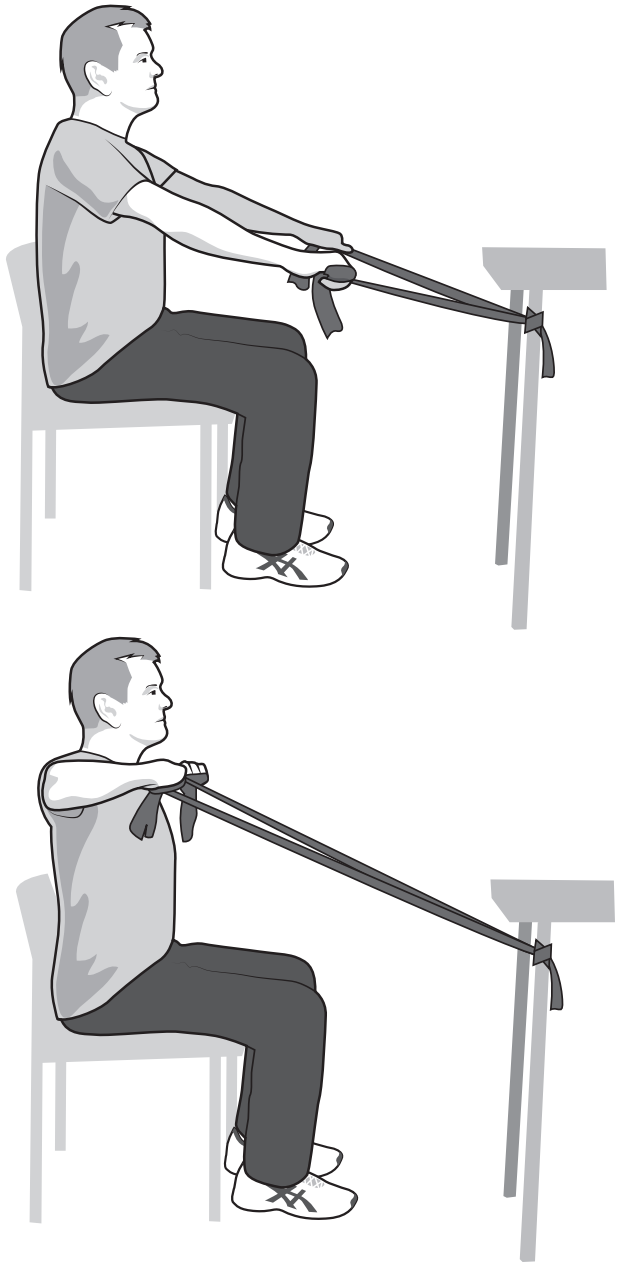
2 Sit holding the end of the band with your arms out straight, palms down and looking ahead.

3 Pull your shoulder blades back and down your back.

4 Slowly bring your hands to your chest as you take your elbows out and then return to the starting position.

5 Make sure not to lift your shoulders as you pull your hands to your chest and keep your shoulders blades back as you return to the starting position.

6 Repeat 10 times.



kg WEIGHT L R

Hand turn up and down

1 Sit on a chair with your elbow supported on books on a table in line with your body.

2 Have your elbow bent to 90° and near the edge of the books and your hand pointing up.

3 Pull your shoulder blades back and down your back.

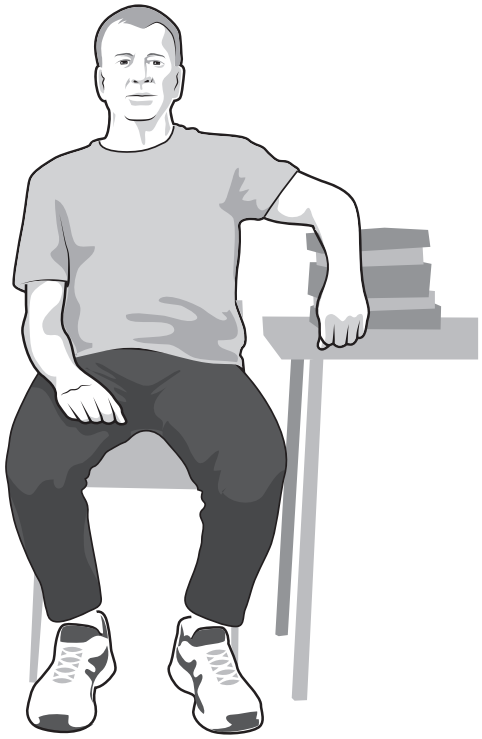
4 Keeping your elbow bent at 90°, slowly turn your forearm down and then back up to the starting position.

5 Make sure to keep your shoulder blades back throughout the turning movement.

6 Repeat 10 times right side.

7 Turn chair around and repeat exercise with other arm.

8 Repeat 10 times left side.



Hand turn in

1 Attach band to a secure point eg rail, door, table leg.

2 Hold the end of the band with your arm by your side and elbow bent.

3 Start with your hand turned out and your shoulder blades back and down your back.

4 Keeping your elbow against your body, slowly turn your hand in and back to the starting position.

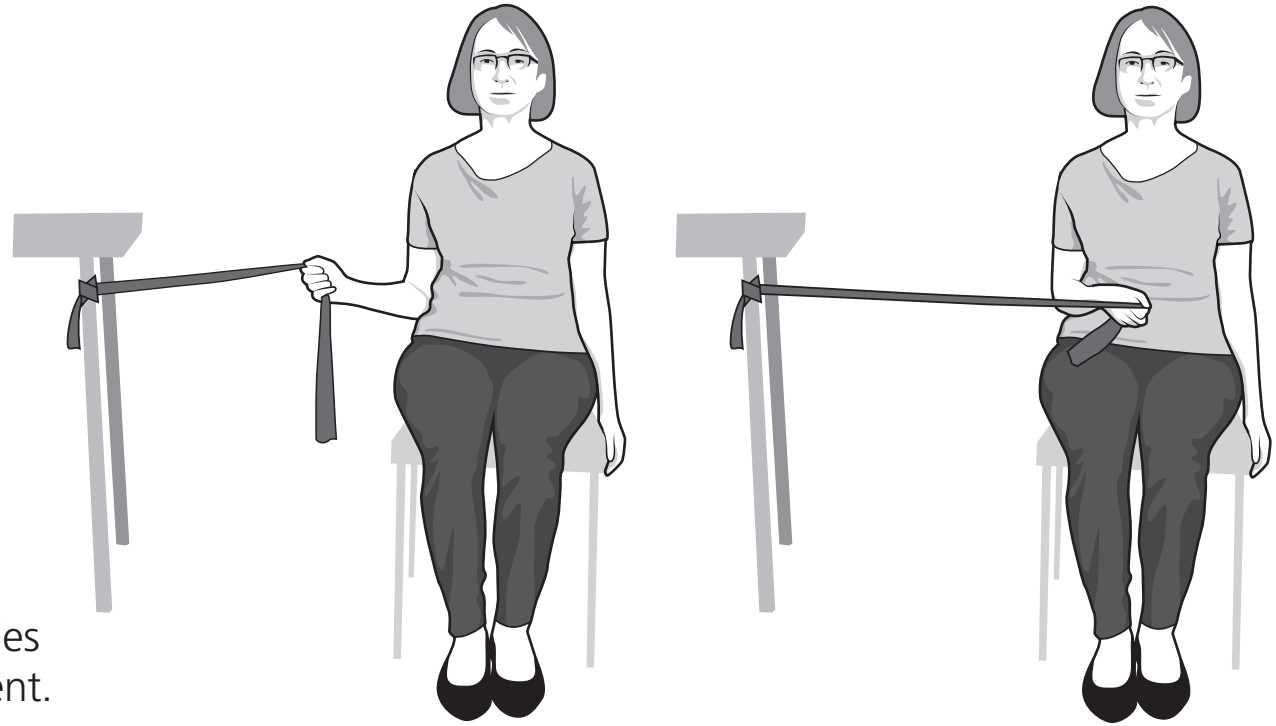
5 Make sure to keep your shoulder blades back throughout the turning movement.

6 Do not turn your body.

7 Repeat 10 times right side.

8 Turn around and hold band with other hand.

9 Repeat 10 times left side.



APPENDIX C:
BEST at Home -
Calendar for recording falls and exercise

Reply Paid 85147, Amanda Bates, ISLHD – Health Promotion Service, Locked Bag 9, Wollongong NSW 2500

December 2017

BEST at Home
Study Calendar

MON	TUE	WED	THU	FRI	SAT	SUN
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

At the end of the month complete and pull out this page.
Place this in one of the envelopes at the back of this folder.
No stamp is required to post the envelope.

Thank you.
Research Team
Ph: 4221 6778

☐ **I had no falls this month**

Participant number ☐☐☐☐

PLEASE MARK THE CALENDAR EACH TIME:

F if you have a **FALL**, then time and place of fall.

D if you see a **DOCTOR** (write GP or Specialist)

H on the days if you are admitted to **HOSPITAL**

E for the days that you complete the **EXERCISES**

IF YOU HAVE AGENCY HELP MARK THE CALENDAR:

S if you have help with **SHOWERING**

C if you have help with **CLEANING**

M for **MEALS** delivered

T for help with **TRANSPORT** and/or shopping

N if you see a **NURSE**

O if you see either a **PHYSIOTHERAPIST**, **OCCUPATIONAL THERAPIST** or **PODIATRIST** (please specify).

APPENDIX D:
BEST at Home - Exercise program manual for COPD pilot

BEST at home
Balance Exercise Strength Training

Welcome to the home-based exercise program

The exercise program that you will undertake has been designed specifically for you.

Exercise has many benefits. By maintaining your exercise program, you can improve:

- Balance
- Muscle strength
- General fitness
- Sleep
- Ability to perform everyday activities
- Mood
- Assist sputum clearance
- Sense of control over lung condition, and
- General well-being

Please ensure that you have taken your respiratory medication/ puffers before you exercise. If you use Home Oxygen please use as prescribed by your GP when exercising.
You can divide the exercises up. They do not all have to be done at the same time.

Between each set of exercises take three deep breaths or more to catch your breath. You can sit down if you need to rest between exercises

You may feel a bit stiff after you first start to exercise. This is quite normal. It is because you are using muscles which may not be used to the exercise. It is important that you keep on exercising. The stiffness will leave as your body becomes more familiar with the exercise.

Please try to do your exercises three times each week.

Please mark on the calendar each day you do the exercises, as shown below. If you have a fall, please record this as well.

E When you do the exercises

F if you have a fall

Please return the calendar at the end of each month via post. Place the calendar in one of the reply-paid envelopes at the back of this folder (no stamp is required to post). Please return the calendar even if you have not done any exercise or have not had a fall.

Getting stronger by using weights

Strengthening your muscles is essential for maintaining healthy bones and muscles necessary for walking and being independent in your daily activities.

- Lift the weight slowly through the entire range of movement.
- Never hold your breath while lifting. Inhale before lifting, exhale while lifting and inhale again while lowering the weight.

Safety

- Take your reliever inhalers before exercising if prescribed by your doctor
- Never exercise holding onto an object which may move, for example a chair.
- Always use the side of something stable like a bench or solid table unless otherwise instructed.
- Always ensure the floor area is clear of clutter and obstacles before starting the exercises.
- Start by doing a small amount of exercise and gradually increase the frequency and duration
- Drink enough fluids – have a water bottle handy as you exercise
- Restart your exercise program at a lower intensity if you have not exercised for a while or if you have been unwell

Intensity of Exercise

We will use the scale below to rate the difficulty of your breathing while you are exercising.

It starts at 0, where your breathing is causing you no difficulty at all and progresses through to 10, where your breathing difficulty is maximal.

Modified Borg Dyspnoea Scale

0	Nothing at all
0.5	Very, very slight (just noticeable)
1	Very slight
2	Slight
3	Moderate
4	Somewhat severe
5	Severe
6	
7	Very severe
8	
9	Very, very severe (almost maximal)
10	Maximal

You should be working hard enough to feel a breathlessness score of 3-4 on the Borg Dyspnoea Scale above.

When to STOP exercising

Stop and rest immediately if you experience any of the following while exercising:

- Dizziness or feeling faint
- Chest pain
- Extreme pain
- Unusual pins and needles or tingling sensations
- Coughing up blood
- Extreme shortness of breath
- Blurred vision

If you experience any of these symptoms, please seek medical attention.
In an emergency, do not hesitate to **call 000**.

If you have any questions about the exercise program please do not hesitate to telephone the BEST at Home research team on **(02) 4221 6728**.

Day to day

Did you know that you can improve your general fitness simply by being more active in your day-to-day life?

Here are some examples of activities to build into your day:

- Walk instead of driving to the shops
- Walk to talk to a neighbour instead of phoning
- Take the stairs rather than the lift or escalator
- Get off the bus a block early and walk home
- When visitors and family arrive, go for a walk with them before having a cup of tea
- Garden when the weather permits
- Stand to fold washing.

Helpful hints

Here are some hints, to help you complete the exercises three times per week.

- Keep this manual in an easy to see place as a reminder.
- You do not need to do all the exercises all at once. You can break up the exercises into smaller portions and complete throughout the day. You just need to make sure that by the end of the day you have completed all the exercises.
- If you complete the exercises in smaller portions, leave the manual open to the exercise you are up to.
- Try to incorporate the exercises into your daily routine, for example:
    - front knee strengthening exercise while watching TV
    - heel toe standing while waiting for the kettle to boil
    - knee bends while talking on the telephone etc.

- Use the calendar provided to keep track of when you complete the exercises.

- Tell friends and/or family members about your exercises and ask them to support you to do the exercises.

- Think about the benefits of improved strength and balance. What is it that you would like to achieve?

- Reward yourself for completing all the exercises at the end of the month.

- Read *'Staying active and on your feet'* for tips on how to stay safe and independent in your home.

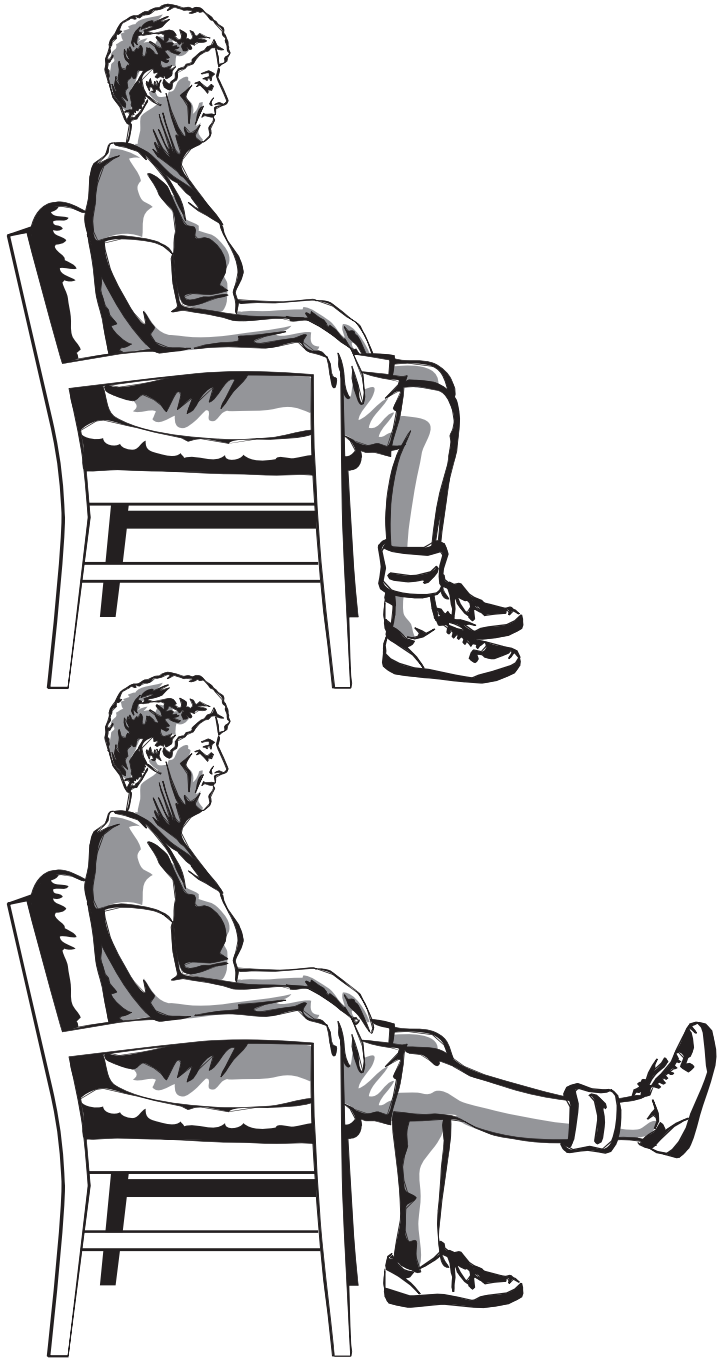
- It can be easy to fall out of an exercise routine due to holidays or ill health. Try not to be discouraged, start up the exercises again and slowly get back into your regular routine.

- Going away? Take your manual and weight with you. It is easy to pack and it will help to keep you in a routine if you continue while on holidays.

- Too easy? Think about the different ways the physiotherapists suggested you could make the exercises harder. For example:
    - Do more repetitions of the exercise
    - Hold the exercise contraction for longer
    - If you feel confident, use less support.

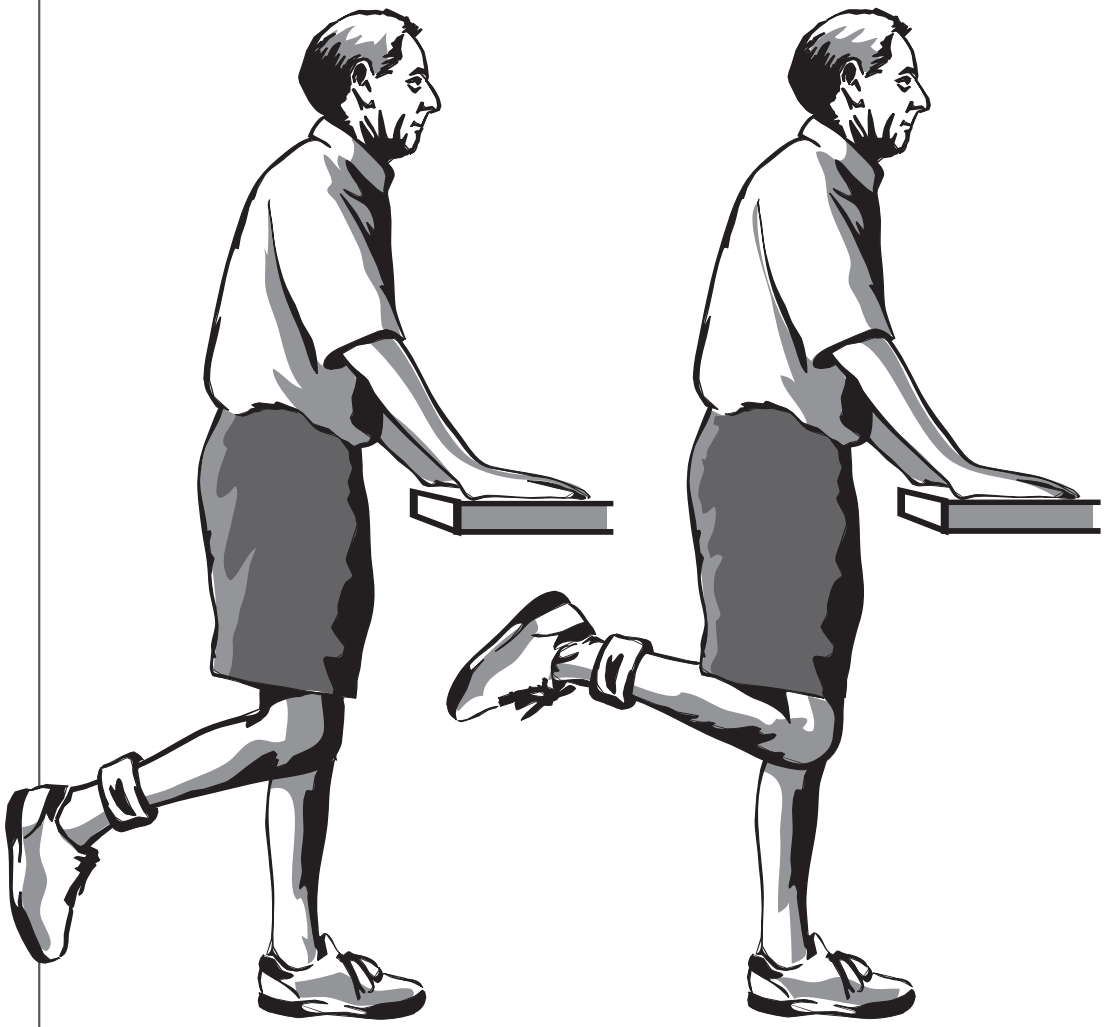
Front knee strengthening exercise

- You could do this exercise while you are watching TV
- Strap the weight on to your ankle
- Sit on a chair with your back well supported
- Straighten the leg out
- Lower the leg
- Repeat ◯ times
- Strap the weight on to the other ankle
- Repeat this exercise ◯ times



Back knee strengthening exercise

- Strap the weight on to your ankle
- Stand up tall facing the bench with both hands on the bench
- Bend the knee, bringing the foot towards your bottom
- Return to the starting position
- Repeat ◯ times
- Strap the weight on to the other ankle
- Repeat this exercise ◯ times

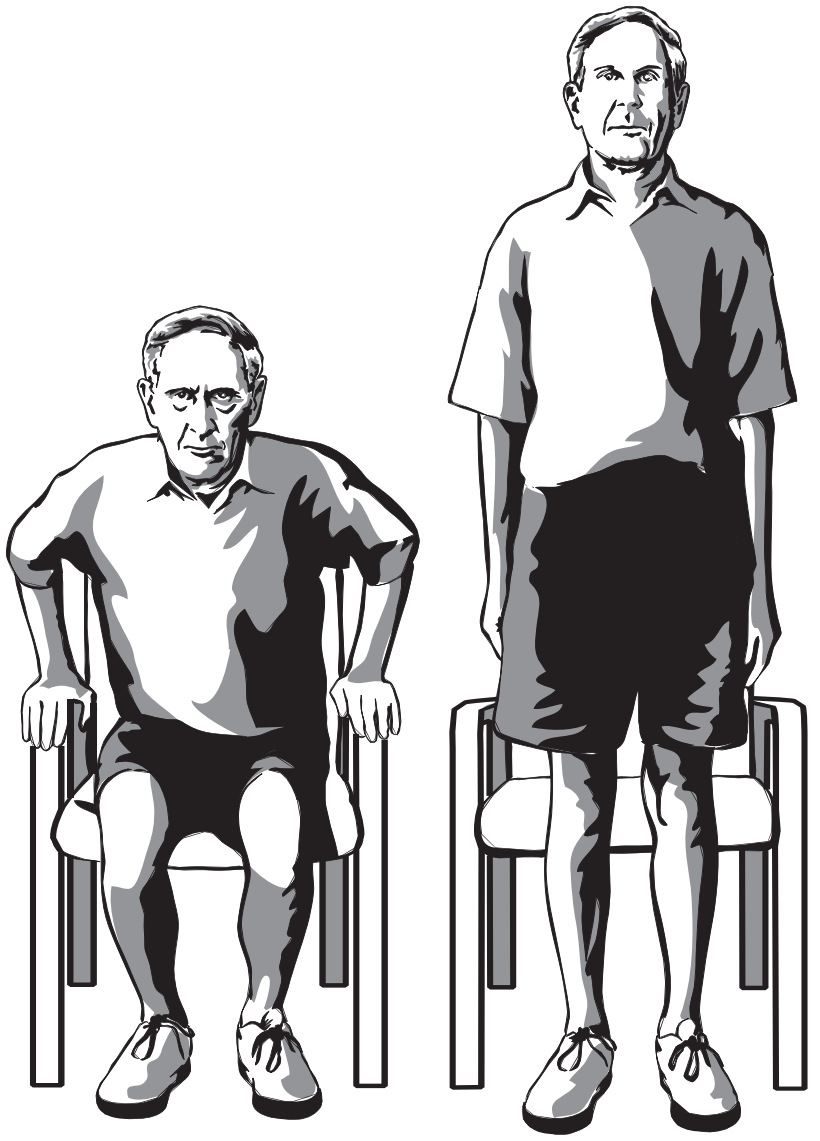


Side hip strengthening exercise

- Strap the weight on to your ankle
- Stand up tall beside the bench
- Hold on to the bench
- Keep the exercising leg straight and the foot straight forward
- Lift the leg out to the side and return
- Repeat ◯ times
- Strap the weight on to the other ankle
- Turn around
- Repeat this exercise ◯ times

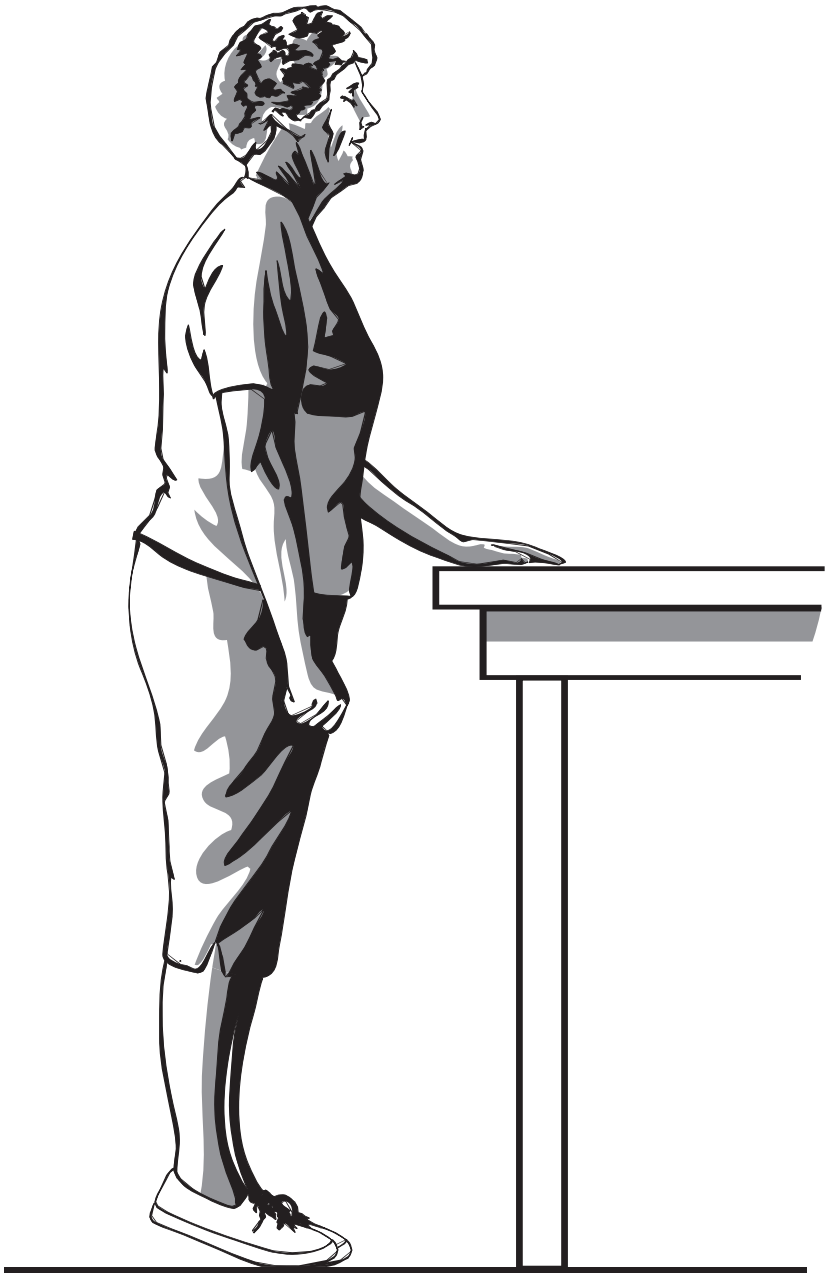
Sit to stand – two hands

- You could do this exercise while you watch TV
- Sit on a chair which is not too low
- Place the feet behind the knees
- Lean forwards over your knees
- Push off with both hands to stand up
- Repeat ◯ times



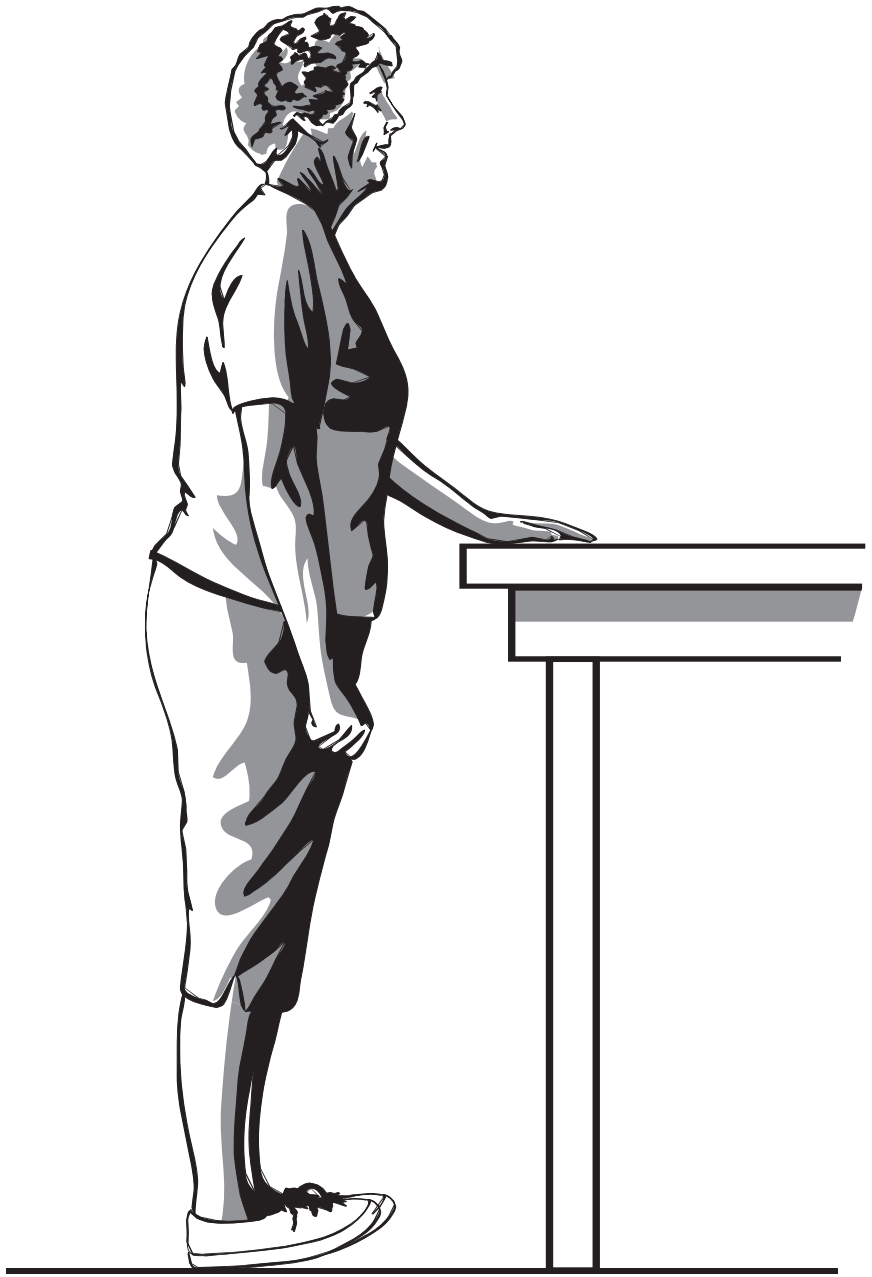
Calf raises – hold support

- Stand up tall facing the bench
- Hold on and look ahead
- The feet are shoulder-width apart
- Come up onto your toes
- Lower the heels to the ground
- Repeat this exercise 20 times



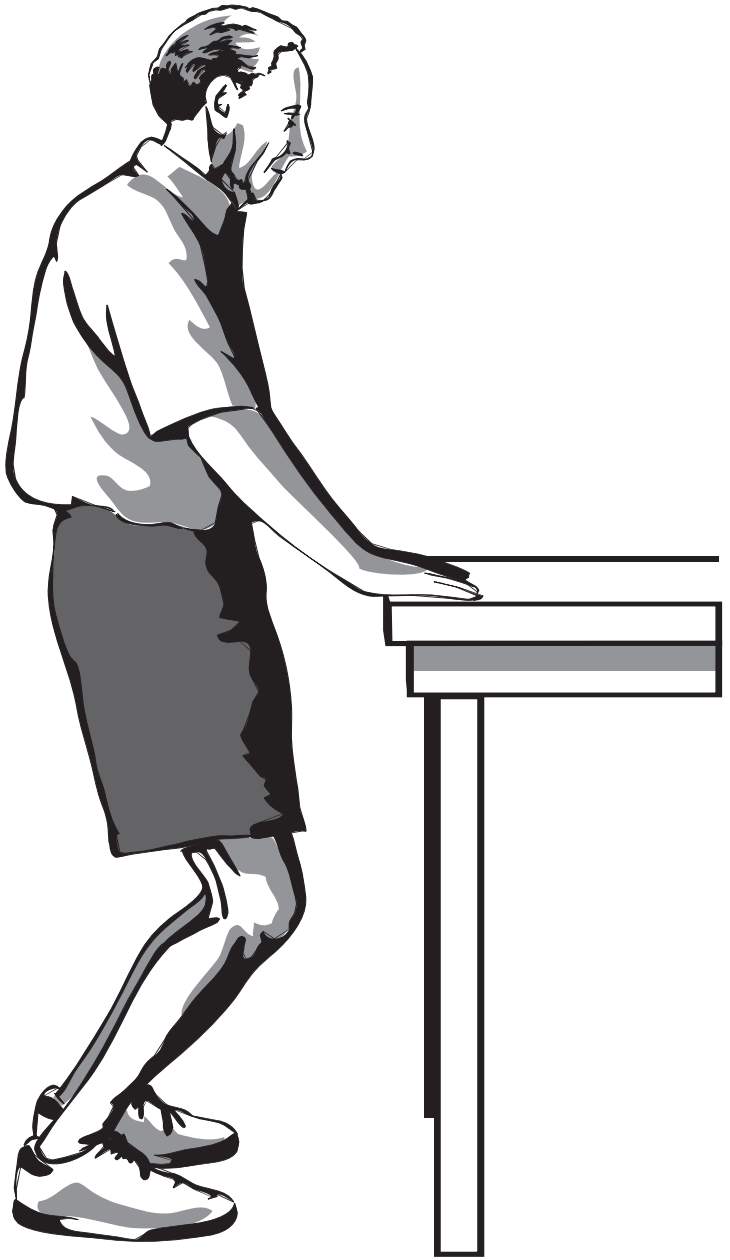
Toe raises – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- The feet are shoulder-width apart
- Come back onto the heels, raising the front foot off the floor
- Lower the feet to the ground
- Repeat this exercise 20 times



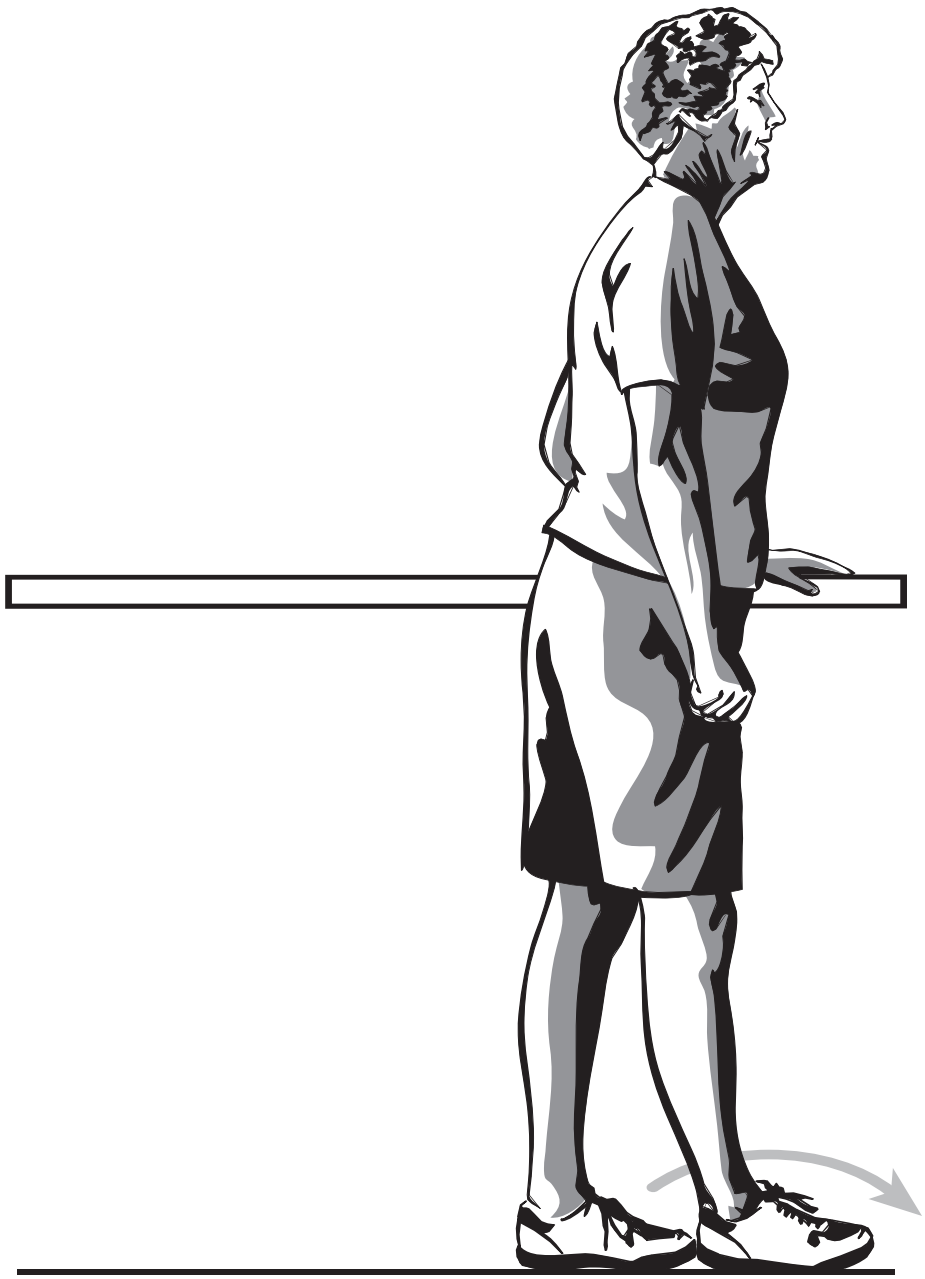
Knee bends – hold support

- Stand up tall facing the bench with both hands on the bench
- Place your feet shoulder-width apart
- Squat down half way, bending your knees
- The knees go over the toes
- When you feel your heels start to lift, straighten up
- Repeat ◯ times



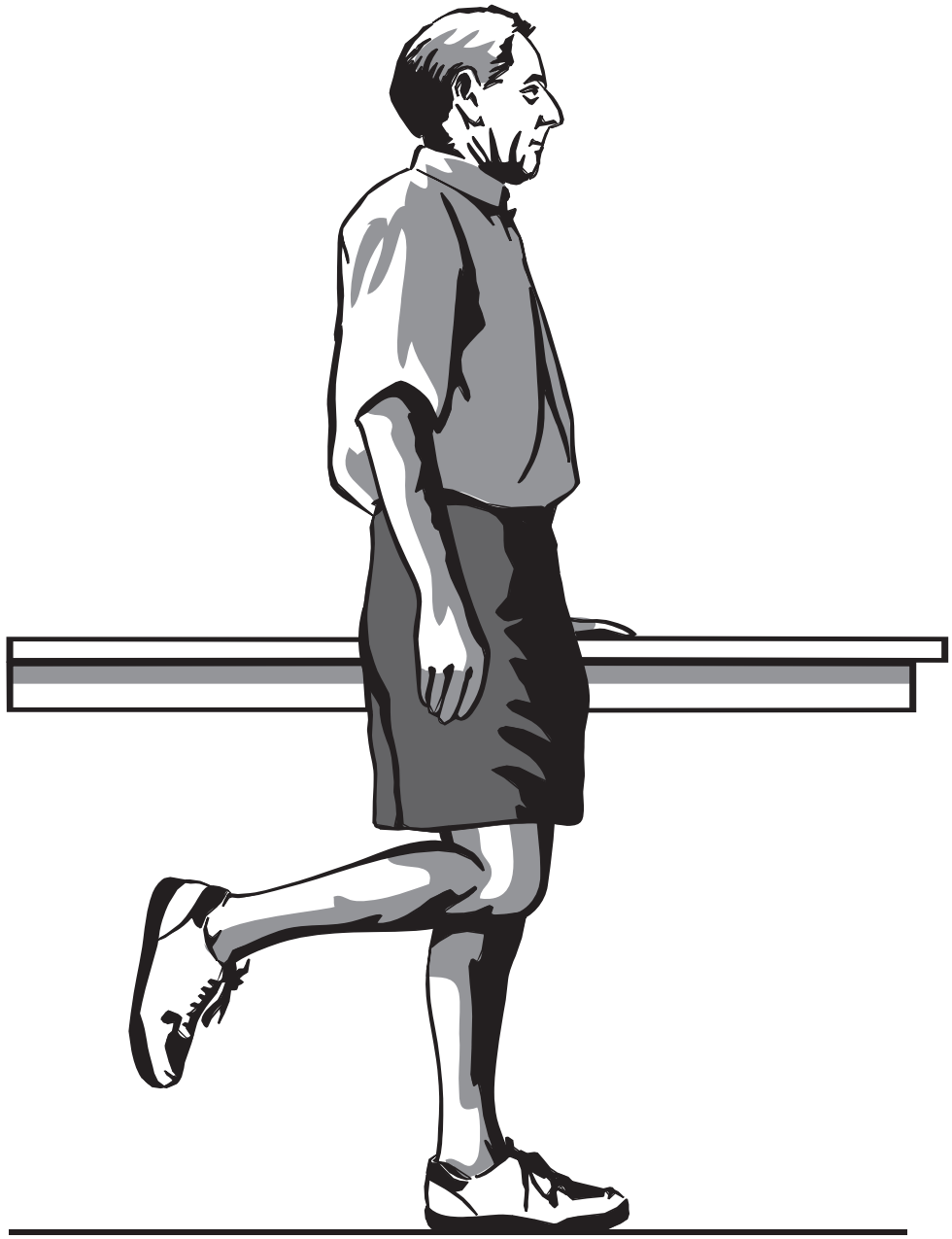
Heel toe standing – hold support

- Stand up tall beside the bench
- Hold on to the bench and look ahead
- Place one foot directly in front of the other foot so the feet form a straight line
- Hold this position for 10 seconds
- Change position and place the foot behind directly in front
- Hold this position for 10 seconds



One leg stand – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Stand on one leg
- Try to hold this position for 10 seconds
- Stand on the other leg
- Try to hold this position for 10 seconds

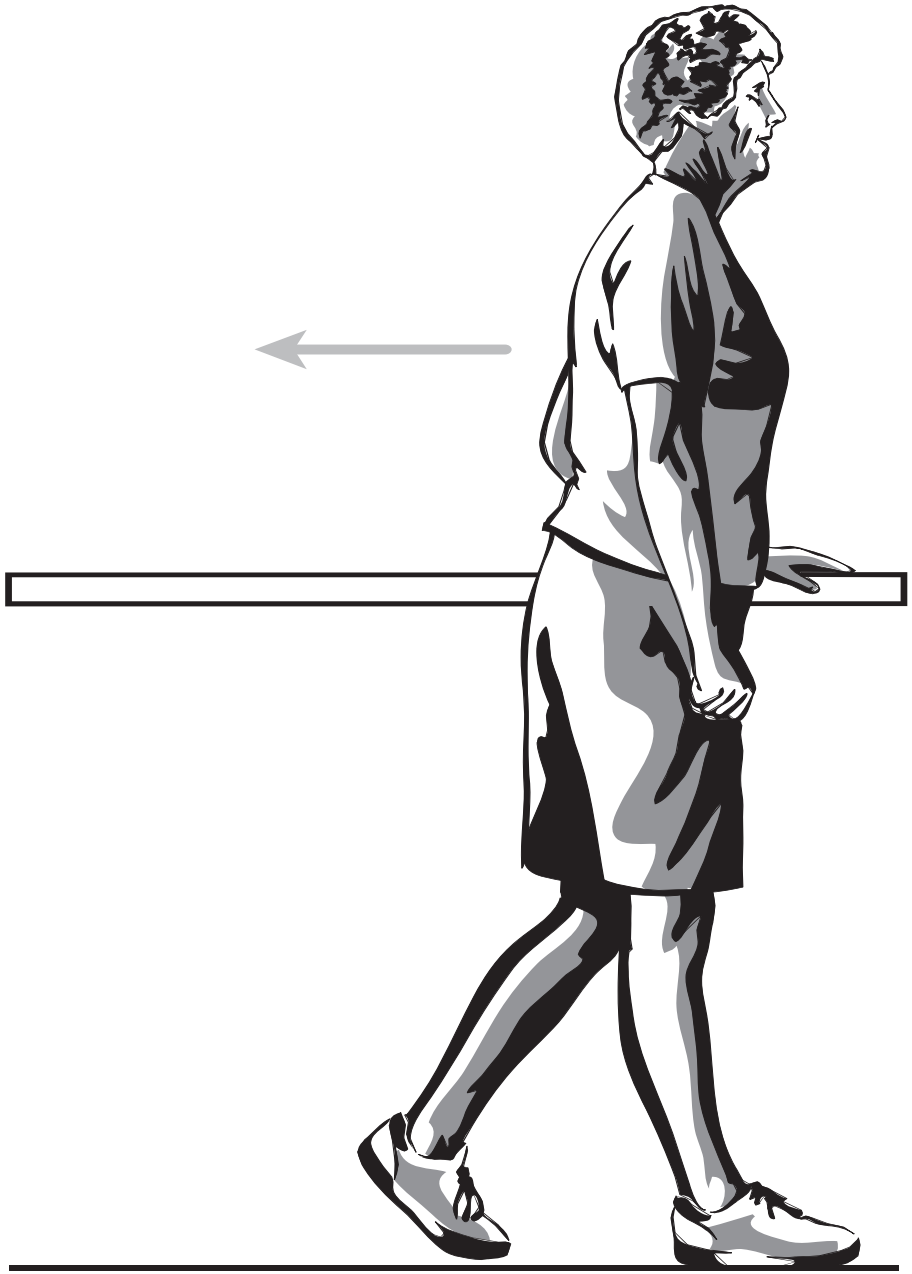


Sideways walking

- Stand up tall and place your hands on your hips
- Take 10 side steps to the right
- Take 10 side steps to the left
- Repeat

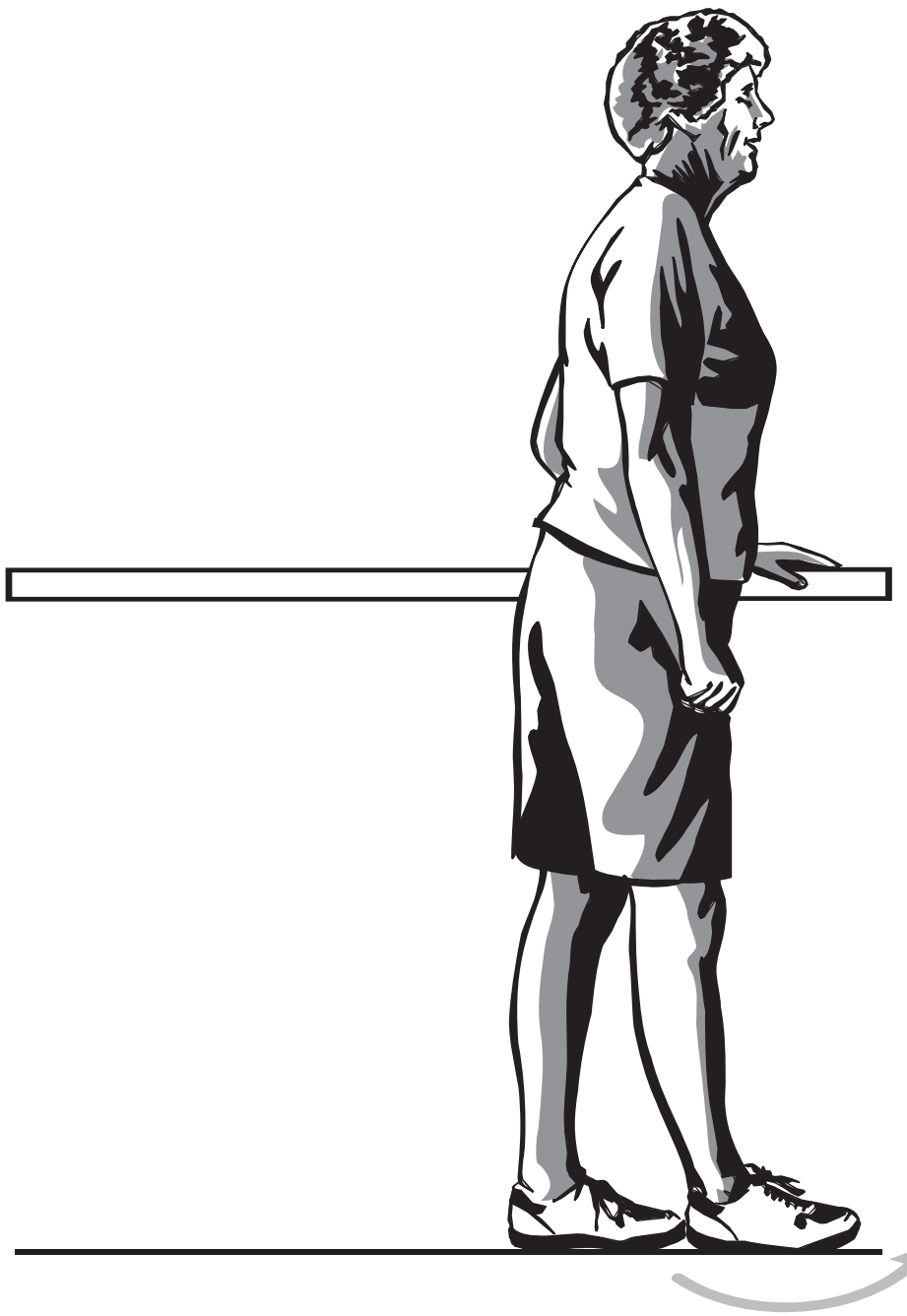
Backwards walking – hold support

- Stand up tall and hold on to the bench
- Walk backwards 10 steps
- Turn around and hold on with the other hand
- Walk backwards 10 steps to the beginning
- Repeat this exercise



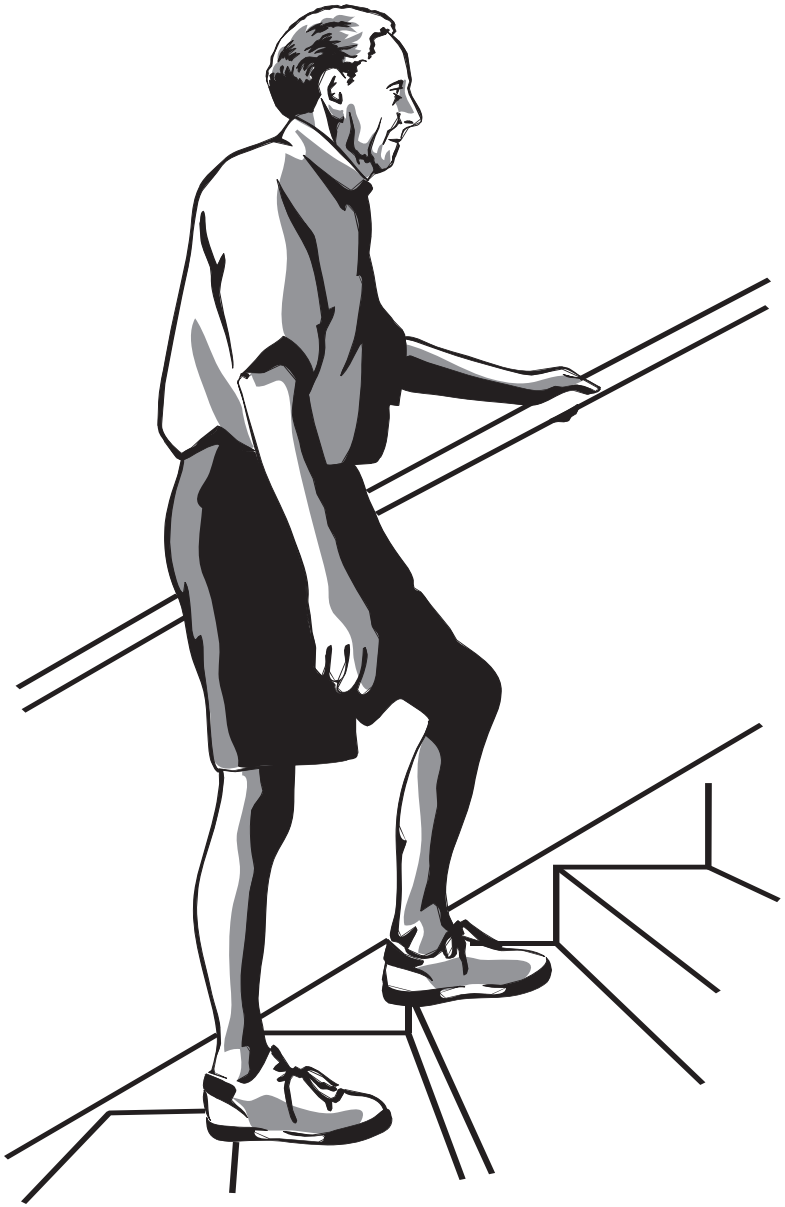
Heel toe walking – hold support

- Stand up tall beside the bench
- Hold on and look ahead
- Place one foot directly in front of the other so they form a straight line
- Place the foot behind directly in front
- Repeat for 10 more steps
- Turn around
- Repeat the exercise



Stair walking

- Hold on to the hand-rail for this exercise
- Go up and down the stairs for ◯ steps



APPENDIX E:
BEST at Home – Ethics approval letter

UNIVERSITY OF WOLLONGONG

AMENDMENT APPROVAL - ISLHD

In reply please quote: HE14/279

Further Enquiries Phone: 4221 3386

19 November 2014

Dr Susan Furber
Health Promotion Service
Illawarra Shoalhaven Local Health District
Locked Bag 9
Wollongong 2500

Dear Dr Furber,

I am pleased to advise that amendments received 13 November 2014 to the following Human Research Ethics application have been **approved.**

Ethics Number:	HE14/279
AuRED Number:	HREC/14/WGONG/50
Project Title:	The BEST at home pragmatic fall prevention program: effectiveness, cost effectiveness and implementation
Name of Researcher/s:	Dr Susan Furber, Professor Catherine Sherrington, Ms Amanda Bates, Ms Michelle Kershaw, Ms Lisa Franco, Dr Paul van den Dolder, Ms Patricia Lynch

Sites/CIs reviewed:

Site	Principal Investigator for site
ISLHD	Dr Susan Furber

Amendment Approval Date:	18 November 2014
Amendments Approved:	Changes to questionnaires, physical assessment forms and DASH questionnaire
Document Reviewed/ Approved:	Revised Baseline physical assessment, version 2, 27/10/14 Revised Wk 12 Physical assessment, version 2, 27/10/14 Revised Wk 26 physical assessment, version 2, 27/10/14 Revised Baseline questionnaire, version 2, 05/11/14 Revised 12 month questionnaire, version 2, 05/11/14 Revised Week 12 questionnaire, version 2, 05/11/14 Revised Week 26 questionnaire, version 2, 05/11/14

Ethics Unit, Research Services Office
University of Wollongong NSW 2522 Australia
Telephone (02) 4221 3386 Facsimile (02) 4221 4338
Email: rso-ethics@uow.edu.au Web: www.uow.edu.au

Expiry Date: 3 November 2015

Please remember that in addition to reporting proposed changes to your research protocol, the HREC requires that researchers immediately report:

- serious or unexpected adverse effects on participants
- unforseen events that might affect continued ethical acceptability of the project.

The University of Wollongong/Illawarra Shoalhaven Local Health District Health and Medical HREC is constituted and functions in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report template is available at http://www.uow.edu.au/research/rso/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School and returned to the Research Services Office prior to the expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

A copy of this advice has been forwarded to the ISLHD for their records.

Yours sincerely,

Associate Professor Sarah Ferber
Chair, UOW & ISLHD Health and Medical
Human Research Ethics Committee

cc: Governance Officer, Research Directorate, ISLHD

APPENDIX F:
BEST at Home – Participant Information Sheet

Participant Information Sheet for the BEST at Home Program

(1) What is the study about?

You are invited to take part in a study entitled: *The Balance, Exercise Strength Training (BEST) at Home program: effectiveness, cost effectiveness and implementation*. This study aims to measure:

a) the effectiveness of a home based exercise program designed to improve strength and balance and reduce the risk of falling, and
b) the impact of an arm exercise program on shoulder pain and function.

Balance and strength exercises have been shown to reduce falls in older people, however new programs are needed to increase and maintain participation in these exercises. The impact of arm exercise on shoulder pain and function is not known.

(2) Who is carrying out the study?

The study is being undertaken by a team of researchers from the Illawarra Shoalhaven Local Health District, the University of Sydney and The George Institute for Global Health led by Professor Cathie Sherrington.

(3) What does the study involve?

If you decide to participate in this research study, you will be randomly allocated to one of two exercise groups which will primarily involve exercises for your arms or your legs. This study involves taking part in three group exercise sessions and three measurement sessions (in a suburb near you). In the first exercise session a physiotherapist will demonstrate a series of exercises for either the upper or lower limb depending on which group you are randomly allocated to. You will be given a booklet with the exercises in it. It is hoped that you will undertake these exercises three times a week and record the exercise, if you experienced any falls and health service use in 12 monthly calendars, which you will mail back to the research centre in reply-paid envelopes. If calendars are not returned, you will be telephoned to ask about your exercise, any falls and health service use during the past month. You may be contacted (via mail or phone) two years and four years after commencement of the study to ask about any falls.

Once it is confirmed that you are eligible to take part in the study, you will be asked to complete a series of questionnaires about your general health, medical and fall history. These questionnaires will also be repeated 3, 6 and 12 months after study commencement. The questionnaires will take about 20 minutes to complete each time.

The questionnaires include questions about your mobility, health, and medical conditions. Examples of questions are below.

What walking aid do you usually use to help you move about inside the house?
[ ] nil, [ ] walking stick, [ ] sticks, [ ] frame, [ ] wheelchair

In general, would you say your health is:
[ ] excellent, [ ] very good, [ ] good, [ ] fair, [ ] poor

You will be also asked to undertake some simple tests of strength and balance such as leg muscle strength, standing balance, walking speed and shoulder range of movement. You will receive instructions on the measures and support from experienced health professionals.

In addition the amount of physical activity you do will be measured at the start of the study and 6 and 12 months after commencement over a 7-day period each time using a matchbox-sized accelerometer. The device is able to accurately estimate how physically active a person is throughout the day. The accelerometer will be posted to you with clear instructions for use and telephone support will be available. You will also be provided with pre-paid envelopes to return the devices.

(4) Who is eligible to take part in the study?

To take part in the study you need to be aged 65 years or older, living in the community and able to walk 10 metres with or without a walking aid but with no help from another person.

You will **not** be able to take part in the study if you have dementia or other cognitive limitations, or if you have insufficient English language skills, or if you have a progressive neurological disease (e.g., Parkinson's disease), or a medical condition precluding exercise (e.g., unstable cardiac disease).

(5) How much time will the study take?

You will be asked to attend three exercise sessions, 3 measurement sessions and perform simple exercises at home 3 times per week. The set of exercises will take approximately 30 minutes to complete. The table below outlines the time required for the workshops and measurement sessions.

Timeline	Activity	Time required
Beginning	• Questionnaire 1 • Measurement session1 • Accelerometer (7-day record)	1 hour
1 week	• Exercise Session 1	1 hour
4 weeks	• Exercise Session 2	1 hour
12 weeks	• Exercise Session 3 • Questionnaire 2 • Measurement session 2	2 hours
6 months	• Questionnaire 3 • Measurement session 3 • Accelerometer (7-day record)	1 hour
9 months	• Phone call	10 minutes
12 months	• Questionnaire 4 (via mail) • Accelerometer (7-day record)	30 minutes
2 years	• Questionnaire 5 (via mail or phone)	10 minutes
4 years	• Questionnaire 6 (via mail or phone)	10 minutes
	Total time required	**7 hours**

(6) Can I withdraw from the study?

Your participation in the study is voluntary and you are able to withdraw at any time. If you do not want to take part in the study or if you do not want to complete the study, this will not affect your relationship with the Illawarra Shoalhaven Local Health District or the University of Sydney.

(7) Will anyone else know the results?

All aspects of the study, including results, will be strictly confidential and only the researchers will have access to information on participants. A report of the study may be submitted for publication in a journal or presented at conferences, but individual participants will not be identifiable in such a report or presentation. All information collected will be kept in locked filing cabinets and password protected databases at the Illawarra Shoalhaven Local Health District Health Promotion Service. Information will be kept for 15 years and will then be destroyed.

(8) Will the study benefit me?

It is hoped that taking part in this study will benefit you by improving your strength, balance or shoulder function. Both groups are expected to benefit from the exercises. The exercises for one group are thought to be more beneficial for balance and preventing falls and the exercises for the other group are thought to be more beneficial for reducing shoulder pain and improving shoulder function.

(9) What are the risks?

While the risk is low, there are some risks associated with taking part in the study. You may experience some muscle soreness at the start of the exercise program. If the exercises are not done correctly there is the possibility that you may hurt yourself eg muscle strain. There may also be a small risk of injury if an exercise band breaks while you are performing the upper limb exercises. To avoid an eye injury, people in the upper limb exercise group will receive safety glasses and a new exercise band at the six month session. At the first exercise session an experienced physiotherapist will demonstrate the exercises and instruct you on how to perform them correctly and safely.

(10) Can I tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) What if I require further information about the study or my involvement in it?

If you are interested in participating or would like more information, please contact Amanda Bates from the Illawarra Shoalhaven Local Health District, Health Promotion Service on (02) 4221 6778 or email amanda.bates@sesiahs.health.nsw.gov.au

(12) What if I have a complaint or any concerns?

This study has been approved by the University of Wollongong and Illawarra Shoalhaven Local Health District's Human Research Ethics Committee. If you have any concerns of an ethical nature or complaints about the manner in which this research is conducted, you can contact the University of Wollongong's Ethics Officer on (02) 4221 3386 or email rso-ethics@uow.edu.au

APPENDIX G:
BEST at Home – Consent form

Consent form for the BEST at Home Program

I have read the participant information sheet for the study entitled: *The Balance, Exercise Strength Training (BEST) at Home: effectiveness, cost effectiveness and implementation* and have had the opportunity to ask questions to one of the researchers from Illawarra Shoalhaven Local Health District or University of Sydney.

I have been advised of the potential risks associated with this study, which include the risk of injury (eg muscle strain) if the study exercises are not done correctly and safely.

I understand my name will not be used on any of the information from the study that is published in journals or presented at conferences.

I understand that I will be asked to mail in 12 monthly calendars reporting exercises, falls and health care information and will receive reminder phone calls/text messages if calendars are not returned.

I understand that I may also be contacted (via mail or telephone) for the follow up aspects of the study at two and four years after commencement of the study.

I understand that my participation in this study is voluntary, I am free to refuse to take part and I am free to withdraw from the study at any time. If I do not want to take part or if I decide not to continue to take part, this will not affect my relationship with the Illawarra Shoalhaven Local Health District.

I understand that I will be randomly allocated to either to one of two exercise groups which will primarily involve exercise for either my arms or my legs.

If I have any enquiries about the study, I can contact Amanda Bates, Health Promotion Service on (02) 4221 6778 or if I have any concerns or complaints regarding the way the study is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on (02) 4221 3386.

By signing below I am showing my consent to take part in the study entitled *The Balance, Exercise Strength Training (BEST) at Home program: effectiveness, cost effectiveness and implementation*

I understand that the information collected from my participation will be used by Illawarra Shoalhaven Local Health District and the University of Sydney to determine if the study can reduce risk of falling and shoulder problems.

Signed **Date**

..../...../.....

Name (please print): .....

Telephone number(s): Home…… Mobile…….

Email address: ……..

APPENDIX H:
BEST at Home – Questionnaire

Participant Number ☐☐☐

BEST at Home - Baseline Questionnaire

Date:_____

First Name: _____ Last Name: _____

Q1.What is your date of birth? _____

Q2. What is your gender? Male / Female / Other

Q3.What is your country of birth? _____

Q4. What language do you speak at home? _____

Q5.Are you of Aboriginal or Torres Strait Islander origin?

[ ] No
[ ] Yes, Aboriginal
[ ] Yes, Torres Strait Islander
[ ] Yes, both Aboriginal and Torres Strait Islander

Q6.What type of accommodation do you live in?

[ ] House
[ ] Unit
[ ] Granny flat
[ ] Independent living unit
[ ] Other (please state) _____

Q7.Who else lives in the home with you?

[ ] I live alone
[ ] I live with my partner only
[ ] I live with my partner and children
[ ] I live with a child/children
[ ] I live with relatives/friends
[ ] Other (please state) _____

Q8.What walking aid do you usually use to help you move about inside the house?

[ ] nil, [ ] walking stick, [ ] sticks, [ ] walking frame, [ ] wheelchair

Q9.What aids do you use to help you move about outside the house?

[ ] nil, [ ] walking stick, [ ] sticks, [ ] walking frame, [ ] wheelchair

Q10.In the last week have you received any assistance from anyone with the following tasks:
Please circle Yes or No for each

Showering	*Yes/ No*	Transport	*Yes/ No*
Dressing	*Yes/ No*	Shopping	*Yes/ No*
Meals	*Yes/ No*	Taking medication	*Yes/ No*
Housework	*Yes/ No*		

Q11.How many falls have you had in the past 12 months? _____

Q12a.Did you sustain any fractures as a result of this/these falls? **Yes / No**

If yes, please give details _____

Q12b.Did you require medical attention as a result of this/these falls? **Yes / No**

Q13.Do you feel your balance is

Excellent	Very Good	Good	Fair	Poor
1	2	3	4	5

Q14.Are you afraid of falling?

not at all	little bit	moderately	quite a lot	extremely
1	2	3	4	5

Q15.How many prescription medications do you currently take, including eye drops? _____

Q16.**Do you have/ have you ever had any of the following?** Please circle yes or no for each

Arthritis (rheumatoid or osteo)	*Yes/ No*	Diabetes	*Yes/ No*
Osteoporosis	*Yes/ No*	Upper gastrointestinal disease	
Asthma	*Yes/ No*	(ulcer, hernia, reflux)	*Yes/ No*
COPD/emphysema	*Yes/ No*	Depression	*Yes/ No*
Angina	*Yes/ No*	Anxiety/panic disorder	*Yes/ No*
Congestive heart failure/heart disease	*Yes/ No*	Visual impairment (cataracts,	
Heart attack (myocardial infarct)	*Yes/ No*	glaucoma, macular degeneration)	*Yes/ No*
Neurological disease (MS or Parkinson's)	*Yes/ No*	Hearing impairment (even with aids)	*Yes/ No*
Stroke/TIA	*Yes/ No*	Degenerative disc disease (back disease,	
Peripheral vascular disease	*Yes/ No*	spinal stenosis, severe chronic back pain)	*Yes/ No*

Q17. **In the past three months, how much time did you spend in the following activities on average per week?**

Never [ ] *Please go to question 18*

Activity type	Number of times/week	Number of minutes per session <30	30-45	45+	1-2hrs	2-4hrs
Activity class (eg. Gentle exercise, dance)	_____	[ ]	[ ]	[ ]	[ ]	[ ]
Home activity (e.g. exercise bike, stretching)	_____	[ ]	[ ]	[ ]	[ ]	[ ]
Other activity 1. Specify: _____	_____	[ ]	[ ]	[ ]	[ ]	[ ]
Other activity 2. Specify: _____	_____	[ ]	[ ]	[ ]	[ ]	[ ]
Other activity 3. Specify: _____	_____	[ ]	[ ]	[ ]	[ ]	[ ]

Q18. During the past three months, how often have you been on walks specifically for activity on average per week? (i.e. walking in the park, in the streets, cross-country walking, walking the dog etc).

[ ] Every day
[ ] 3-6 times/week
[ ] Twice/week
[ ] Once/week
[ ] Less than once/week
[ ] Never *(please go to question 20)*

Q19. In these walks for activity, how long did you walk for?

[ ] Less than 15mins/day
[ ] 15mins to less than 30mins/day
[ ] 30mins to less than 1 hour/day
[ ] 1 hour to less than 2 hours/day
[ ] 2 hours to less than 4 hours/day
[ ] 4 or more hours/day

Q20. During the past three months, how often have you been on other walks (i.e. walk to general practitioner, pharmacy, or store) on average per week.

[ ] Every day
[ ] 3-6 times/week
[ ] Twice/week
[ ] Once/week
[ ] Less than once/week
[ ] Never *(please go to question 22)*

Q21. In these other walks, how long did you walk for?

[ ] Less than 15mins/day
[ ] 15mins to less than 30mins/day
[ ] 30mins to less than 1 hour/day
[ ] 1 hour to less than 2 hours/day
[ ] 2 hours to less than 4 hours/day
[ ] 4 or more hours/day

Q22. In the past three months, in addition to the walking you mentioned above, how much time did you spend each day out of your house doing other physical activity such as house maintenance and gardening? (Excluding housework and activities inside the house)

[ ] Never (i.e. no garden)
[ ] Less than 15mins/day
[ ] 15mins to less than 30mins/day
[ ] 30mins to less than 60mins/day
[ ] 1 hour to less than 2 hours/day
[ ] 2 hours to less than 4 hours/day
[ ] 4 or more hours/ day

Q23. In the past three months, how many hours did you spend on your feet each day indoors at home doing tasks like housework, self care or care for another person?

[ ] Never (i.e. assisted living)
[ ] Less than 15mins/day
[ ] 15mins to less than 30mins/day
[ ] 30mins to less than 60mins/day
[ ] 1 hour to less than 2 hours/day
[ ] 2 hours to less than 4 hours/day
[ ] 4 or more hours/day

Q24. Now we would like to ask some questions about **how concerned you are about the possibility of falling**. Please reply thinking about how you usually do the activity. If you currently don't do the activity, please answer to show whether you think you would be concerned about falling IF you did the activity. For each of the following activities, please mark the box which is closest to your own opinion to show how concerned you are that you might fall if you did this activity.

	Not at all concerned	Somewhat concerned	Fairly concerned	Very concerned
Getting dressed or undressed	1	2	3	4
Taking a bath or shower	1	2	3	4
Getting in or out of a chair	1	2	3	4
Going up or down stairs	1	2	3	4
Reaching for something above your head or on the ground	1	2	3	4
Walking up or down a slope	1	2	3	4
Going out to a social event	1	2	3	4

Q25.The following statements relate to how confident you are that you can carry out regular physical activities and exercise. Please select a level of agreement for each statement by marking the appropriate box.

I am confident….	**Disagree a lot**	**Disagree**	**Not sure**	**Agree**	**Agree a lot**
1. that I intend to become more physically active in the next 6 months	1	2	3	4	5
2. that I can overcome barriers and challenges with regard to physical activity and exercise if I try hard enough	1	2	3	4	5
3. that I can motivate myself to start being physically active or exercising again after I've stopped for a while	1	2	3	4	5

Q26.Please select one response to each of the statements below.

When I am active……	Disagree a lot	Disagree	Not sure	Agree	Agree a lot
4. I enjoy it	1	2	3	4	5

When I am active……	Disagree a lot	Disagree	Not sure	Agree	Agree a lot
5. I dislike it	1	2	3	4	5

Q27. In general, would you say your health is:

Excellent	Very good	Good	Fair	Poor
1	2	3	4	5

Q28.The following questions are about activities you might do during a typical day. **Does <u>your health now limit you</u>** in these activities? If so, how much?

		Yes, limited a lot	Yes, limited a little	No, not limited at all
a.	<u>Vigorous activities</u>, such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b.	<u>Moderate activities</u>, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c.	Climbing <u>several</u> flights of stairs	1	2	3
d.	Bathing or dressing your self	1	2	3

Q29. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities **<u>as a result of your physical health</u>**?

		All of the time	Most of the time	Some of the time	A little of the time	None of the time
a.	<u>Accomplished less</u> than you would like	1	2	3	4	5
b.	Were limited in the <u>kind</u> of work or other activities	1	2	3	4	5

Q30. During the <u>past 4 weeks</u>, how much of the time have you had any of the following problems with your work or other regular daily activities **<u>as a result of any emotional problems</u>** (such as feeling depressed or anxious)?

		All of the time	Most of the time	Some of the time	A little of the time	None of the time
a.	<u>Accomplished less</u> than you would like	1	2	3	4	5
b.	Did work or other activities <u>less carefully than usual</u>	1	2	3	4	5

Q31. How much bodily pain have you had during the past 4 weeks?

No bodily pain	Very mild	Mild	Moderate	Severe	Very severe
1	2	3	4	5	6

Q32. During the <u>past 4 weeks</u>, how much did **<u>pain</u> interfere with your normal work** (including both work outside the home and housework)?

Not at all	A little bit	Moderately	Quite a bit	Extremely
1	2	3	4	5

Q33. These questions are about how you feel and how things have been with you <u>during the past 4 weeks</u>. For each question, please give the one answer that comes closest to the way you have been feeling. **How much of the time** during the <u>past 4 weeks</u>...

		All of the time	Most of the time	Some of the time	A little of the time	None of the time
a.	Have you been a very nervous person?	1	2	3	4	5
b.	Have you felt calm and peaceful?	1	2	3	4	5
c.	Did you have a lot of energy?	1	2	3	4	5
d.	Have you felt downhearted and depressed?	1	2	3	4	5

Q34.During the <u>past 4 weeks</u>, how much of the time has your **<u>physical health or emotional problems</u> interfered with your social activities** (like visiting friends, relatives, etc.)?

All of the time	Most of the time	Some of the time	A little of the time	None of the time
1	2	3	4	5

Q35.Do you have one or more people in whom you can confide? Yes / No

Q36. To what degree does your primary confidant encourage you in your endeavours?

Strongly discourages	discourages	neutral	encourages	Strongly encourages
1	2	3	4	5

APPENDIX I:
BEST at Home – Physical assessment

Participant Number ☐☐☐

The BEST at Home program
Baseline Physical Assessment

Name: _____ Date: _____

Participant to remove shoes and socks for the following tests.

Height (cm) ☐☐☐.☐ **Weight (kg)** ☐☐☐.☐

1. Standing Balance:
Instructions to participant: "Use your legs for balance but do not use your arms. Try to hold this position until I say stop (10 sec.) It helps to keep your balance by looking up and straight ahead".

If unable to complete circle why: (refused / tired / couldn't assess / ☐ physically unable)

1. Physically unable to complete			☐
2. Feet apart (with physical assistance)	yes / no	If less than 10 sec how many sec completed?	☐
3. Feet apart (no assistance)	yes/no	If less than 10 sec. how many seconds completed?	☐
4. Feet together	yes/no	If less than 10 sec. how many seconds completed?	☐
5. Semi Tandem	yes/no	If less than 10 sec. how many seconds completed?	☐
6. Tandem	yes/no	If less than 10 sec. how many seconds completed?	☐
7. Single leg stance	yes/no	If less than 10 sec how many seconds completed?	☐

Score: at level of greatest ability. (ie. 1- 7) ☐

2. Sit to stand 5 times (45 cm chair)
Instructions to participant: "Now we will complete the sit to stand test. This test involves me timing how long it takes you to stand up and sit down five times from a seated position on this chair. Throughout the test I would like you to keep your arms folded in front of you."

If unable to complete circle why: (refused / tired / couldn't assess / physically unable)
1. Physically unable to complete
2. Able to complete with physical assistance yes / no (circle one)
3. Able to complete with hands used yes / no (circle one)
4. Able to complete independently (no assistance required) yes / no (circle one)
   If yes, time to complete independently: ☐☐☐.☐☐ sec

Score: 1= unable, 2= with assistance, 3= using arms, 4= independently ☐

3. Alternate Step test: (time taken for participant to complete 8 foot taps onto a 18 cm. block, alternating right and left feet)
Instructions to participant: "Now I will ask you to do a stepping task. I would like you to complete 8 foot taps up onto this step as quickly as possible, alternating right and left feet. You don't need to actually step up onto the step but you need to place your whole foot onto the step each time."

If unable to complete circle why: (refused / tired / couldn't assess / physically unable)
If yes, time to complete independently: ☐☐☐.☐☐ sec

Shoes and socks may be worn for the remaining tests

4. Knee extensor strength on right and left legs.

Instructions: attach digital weight scale 5 cm above lateral malleolus, repeat 3 times and record best result.

Instructions to participant: "At a moderate pace push against the strap as strongly as you can. You can hold on to the sides of the chair for support as you push. Rest" Repeat "push" or "keep going" loudly three times and tell them the score when they are rested. "Now, again - as strongly as you can. See if you can do even better"

If unable to complete circle why: (refused / tired / couldn't assess / physically unable)

Right ☐☐.☐☐ kg **Left** ☐☐.☐☐

5. Gait Speed: Timed 4 metre walk

Instruction to participant: When I say 'go' walk as fast but as safely as you can till I say 'stop'.

If unable to complete circle why: (refused / tired / couldn't assess /physically unable)

Walking aid used: (0 = none, 1 = 1 stick, 2 = 1 quad sticks, 3 = 2 sticks, 4 = crutches, 5 = PUF, 6 = rollator, 7 = forearm support frame)

Time taken to walk 4 m ☐☐.☐☐ sec 2nd test ☐☐.☐☐ sec

6. Isometric shoulder internal and external rotation force (left and right)

- Subject in crook lying (supine with knees bent) with the shoulder at 90 degrees abduction using a hand-held dynamometer
- Arm fully supported in coronal plane, elbow flexed to 90 degrees and the forearm pronated.
- Dynamometer placed just proximal to the ulnar styloid process.
- Subject asked to build to a maximum contraction over a one to two second period and then hold for a further four to five seconds. Record maximum force produced

Right: Internal rotation force ☐☐.☐ **kg** **Pain Y/N**

: External rotation force ☐☐.☐ **kg** **Pain Y/N**

Left : Internal rotation force ☐☐.☐ **kg** **Pain Y/N**

: External Rotation force ☐☐.☐ **kg** **Pain Y/N**

7. Active shoulder internal and external rotation range of motion (left and right)

- Subjects in crook lying with their shoulder abducted to 90 degrees in the coronal plane and elbow flexed to 90 degrees.
- Internal and external rotation ROM measured with inclinometer from the vertical

Right: Internal rotation ROM ☐☐☐.☐ **degrees** **Pain Y/N**

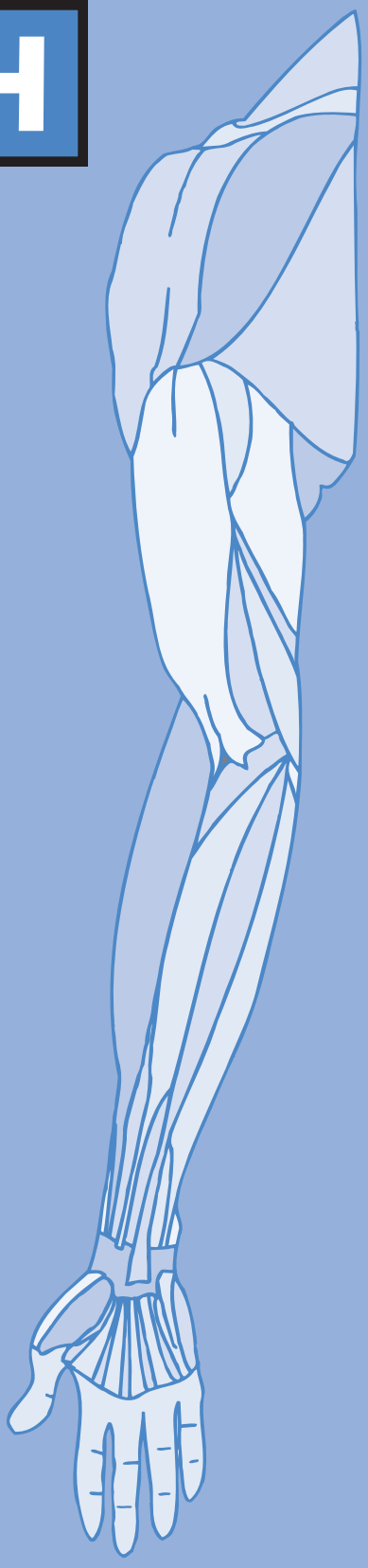
: External rotation ROM ☐☐☐.☐ **degrees** **Pain Y/N**

Left : Internal rotation ROM ☐☐☐.☐ **degrees** **Pain Y/N**

: External rotation ROM ☐☐☐.☐ **degrees** **Pain Y/N**

APPENDIX J:
BEST at Home – DASH questionnaire

THE DASH



INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities.

Please answer *every question*, based on your condition in the last week, by circling the appropriate number.

If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate.

It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

Disabilities of the Arm, Shoulder and Hand

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door .	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 4.5kgs/10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? (circle number)	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? (circle number)	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. (circle number)

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? (circle number)	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. (circle number)	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\frac{\text{sum of n responses}}{n} - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are greater than 3 missing items.

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